ORDER

6830.5

CRITERIA FOR SITING

MICROWAVE LANDING SYSTEMS (MLS)

JULY 22, 1993

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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RECORD OF CHANGES

DIRECTIVE NO. 6830.5

CHANGE TO BASIC	SUPPLEMENT			OPTIONAL	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL

FOREWORD

This order provides guidance to engineering personnel engaged in the siting of FAA microwave landing systems (MLS). It provides information that will enable the engineer to select the optimum site, within defined limits, for each of the subsystems.

This order also augments information available in manufacturer instruction books and other agency directives and complements Order 8260.36, Civil Utilization of MLS.

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and Landing

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CHAPTER 1. INTRODUCTION

100. PURPOSE. This order provides an aid to engineering personnel engaged in the siting of FAA microwave landing systems (MLS). Sufficient information, supplemented by relevant drawings, will enable the engineer to select the optimum site, within defined limits, for each of the subsystems.

101. DISTRIBUTION. This order is distributed to division level in the Air Traffic Plans and Requirements, NAS Systems Engineering, NAS Transition and Implementation, Systems Maintenance, and the Flight Standards Services, Offices of the Aviation System Standards, Airport Safety and Standards, and Program Director Navigation and Landing; to branch level in the regional Airway Facilities, Flight Standards and Airports divisions.

102. BACKGROUND. The concepts of the MLS date back to the early 1950's. From this time it has seen various improvements, electronic scanning and solid state digital electronics to name two, which have contributed to the development of the present day MLS.

a. Design. MLS is designed to be an all-weather precision approach and landing system capable of meeting signal guidance accuracies equivalent to International Civil Aviation Organization (ICAO) Category III standards.

b. Signal Format. MLS operates with an internationally standardized signal format. Thus, any aircraft equipped with a standard MLS receiver can make a guided approach to any MLS-equipped runway.

c. Guidance Coverage. MLS also offers a large volume of guidance coverage, which allows for various curved approaches. This is desirable for noise abatement, airport capacity improvements, or other special conditions.

d. Data Link. MLS also provides a continuous ground-to-air data link to the aircraft. Its modular design makes it flexible and capable of meeting the needs of individual installations.

103. APPLICATION. The criteria set forth in this order apply only to new establishments or relocated facilities. Changes to existing facilities for the sole purpose of obtaining compliance with this criteria are not required.

104. DIRECTIVE VERBS. The material in this order contains FAA criteria, policy statements, recommended practices, and other guidance material which require the use of certain directive verbs such as SHALL, SHOULD, WILL, and MAY. In this order the explicit meaning of the verbs is as follows:

a. SHALL - The action is mandatory.

b. SHOULD - The action is desirable or recommended.

c. WILL - The action is to be taken in the future.

d. MAY - The action is permissible.

105. OUTLINE OF CHAPTERS.

a. Chapter 1 is a brief presentation of the background of the MLS along with the rationale for its development.

b. Chapter 2 begins with a general discussion of MLS and its theory of operation, as well as its growth potential and operational capabilities.

c. Chapter 3 is devoted to MLS power and site preparation requirements.

d. Chapter 4 introduces a general discussion on topics germane to siting, such as critical areas, multipath, and shadowing.

e. Chapter 5 discusses basic siting criteria.

f. Chapter 6 is concerned with specific criteria developed from the analysis of propagation anomalies (multipath, shadowing, etc.), and a discussion of computer modeling to aid in siting.

g. Chapter 7 covers heliport siting.

106. USER PREREQUISITES. This order assumes that the reader has an engineering background and a knowledge of the operating principles of the MLS. In addition, this order does not attempt to duplicate all information found in other applicable FAA documents. The user is expected to have access to and a working knowledge of those documents found in appendix 2. The information and procedures described herein as far as is practical, present qualitative methods for siting an MLS. However, unexpected complexities often arise in complicated airport environments, thus, good engineering judgment shall be essential.

107. RATIONALE FOR THE DEVELOPMENT OF MLS.

a. Overcomes Instrument Landing System (ILS) Limitations. MLS overcomes the single approach-path limitations of ILS and provides improved approach guidance which will meet requirements predicted for the foreseeable future. In addition, MLS will provide 200 separate frequency channels which will relieve the frequency congestion experienced with ILS.

b. Wide Proportional Guidance. The MLS format can provide proportional guidance over a maximum service volume of ±60 degrees in azimuth (AZ) and up to +30 degrees in elevation (EL), permitting segmented and curved approaches, and a selectable glide angle. (Typically proportional guidance is ±40 degrees in AZ and +15 degrees in EL.) This capability allows the selection of approach profiles that best fit the performance capabilities of the aircraft, maximizes the number of approach aircraft by making possible a more efficient use of approach airspace, and enhances noise abatement by allowing specialized approach and departure paths which avoid nearby communities.

108. ADVANTAGES OF THE MLS.

a. Physically Small Antennas. Employing microwave frequencies allows MLS antennas to have large apertures (in terms of wavelengths) while being relatively small physically. Large aperture antennas are capable of producing a narrow beam in space. This characteristic can be used by the siting engineer to minimize the effect of reflected radio-frequency (RF) energy from hangars, airport buildings, and aircraft on the ground.

b. Less Vulnerable. Unlike ILS, MLS antennas do not rely upon a large ground plane to establish the signal in space, and thus MLS is less vulnerable to terrain effects. This fact, plus the small physical size of the MLS antennas, allows more flexibility and reduced costs in siting.

c. Digital Signal Processing. Processing is incorporated in the MLS receiver to reduce the effects of multipath, along with the capability to receive data. Such information as azimuth angle coverage, runway heading, and minimum glidepath is transmitted to the aircraft continuously via data link.

d. Design. Through the use of digital design and microwave RF, MLS provides 200 channels, increased operational capabilities, high reliability, excellent signal quality and guidance, and the flexibility to meet difficult siting requirements.

109.-199. RESERVED.

CHAPTER 2. DESCRIPTION OF MLS

SECTION 1. GROUND SYSTEM LAYOUT

200. MLS GROUND SYSTEM. The FAA standard MLS ground system configuration consists of the following (see figure 2-1):

a. Approach AZ station (including DME/P).

b. Approach EL station.

201. APPROACH AZIMUTH AND PRECISION DISTANCE MEASURING EQUIPMENT (DME) STATION. The approach AZ station is normally located beyond the stop end of the runway. Figures 2-2 and 2-3 show the structure of a typical approach AZ equipment; the exact design of the equipment to be installed may be different depending upon type of antenna and manufacturer. It may or may not be tower-mounted depending upon siting considerations.

a. This station provides lateral guidance, range information, and data transmission to aircraft on approach and is composed of:

(1) Approach AZ equipment.

(a) Data transmission equipment (basic and auxiliary).

(b) AZ equipment electronics.

(c) AZ executive monitor.

(d) A set of cables, waveguides, connectors, and fittings.

(e) One of the following azimuth antenna options.

1 Two-degree beamwidth, ± 40 degrees proportional lateral coverage.

2 One-degree beamwidth, ± 40 degrees proportional lateral coverage.

3 One-degree beamwidth, ± 60 degrees proportional lateral coverage.

4 Three-degree beamwidth, ± 40 degrees proportional lateral coverage.

FIGURE 2-1. STANDARD MLS GROUND SYSTEM CONFIGURATION

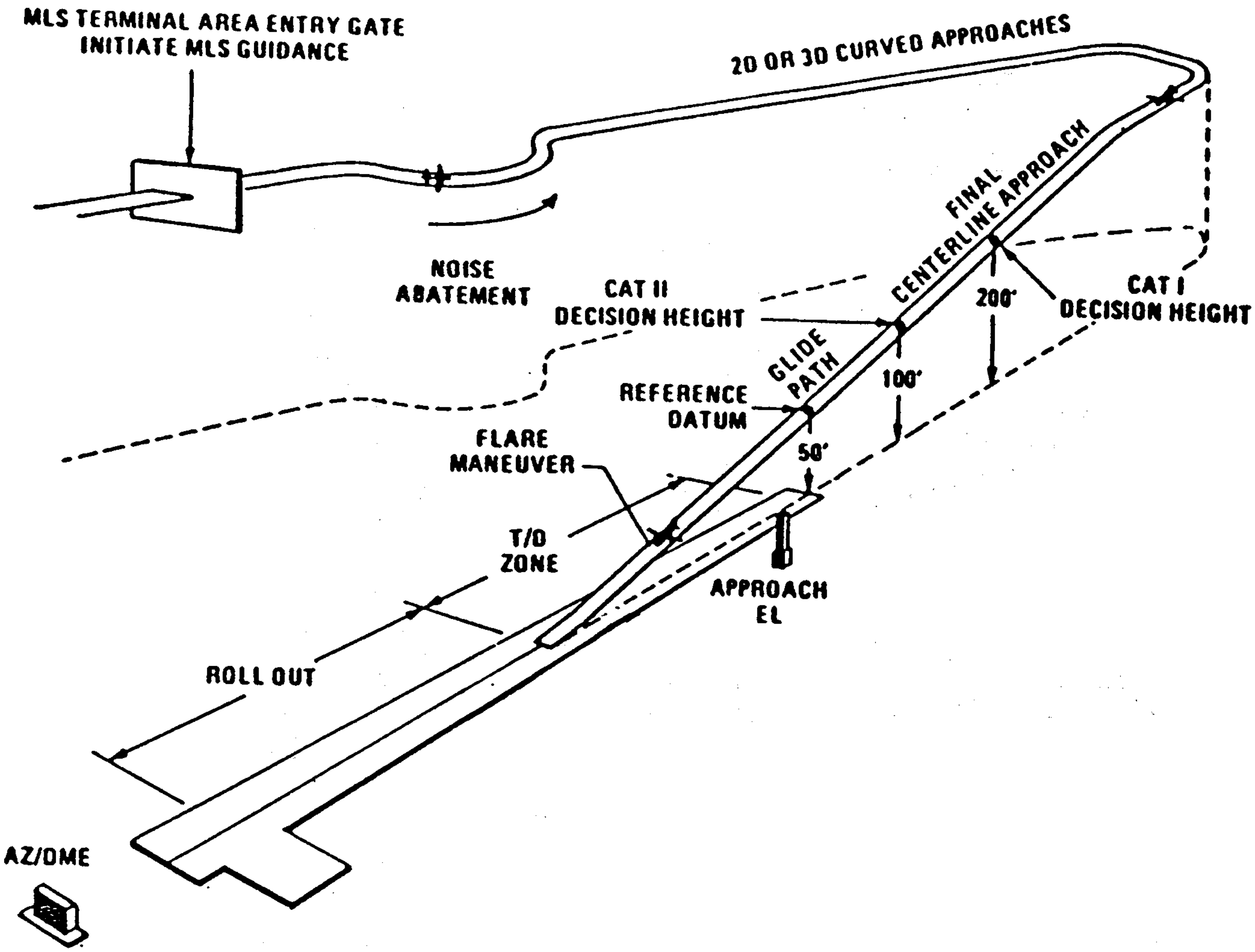


FIGURE 2-2. 2-DEGREE BEAMWIDTH AZIMUTH EQUIPMENT
(TOWER MOUNT SHOWN)

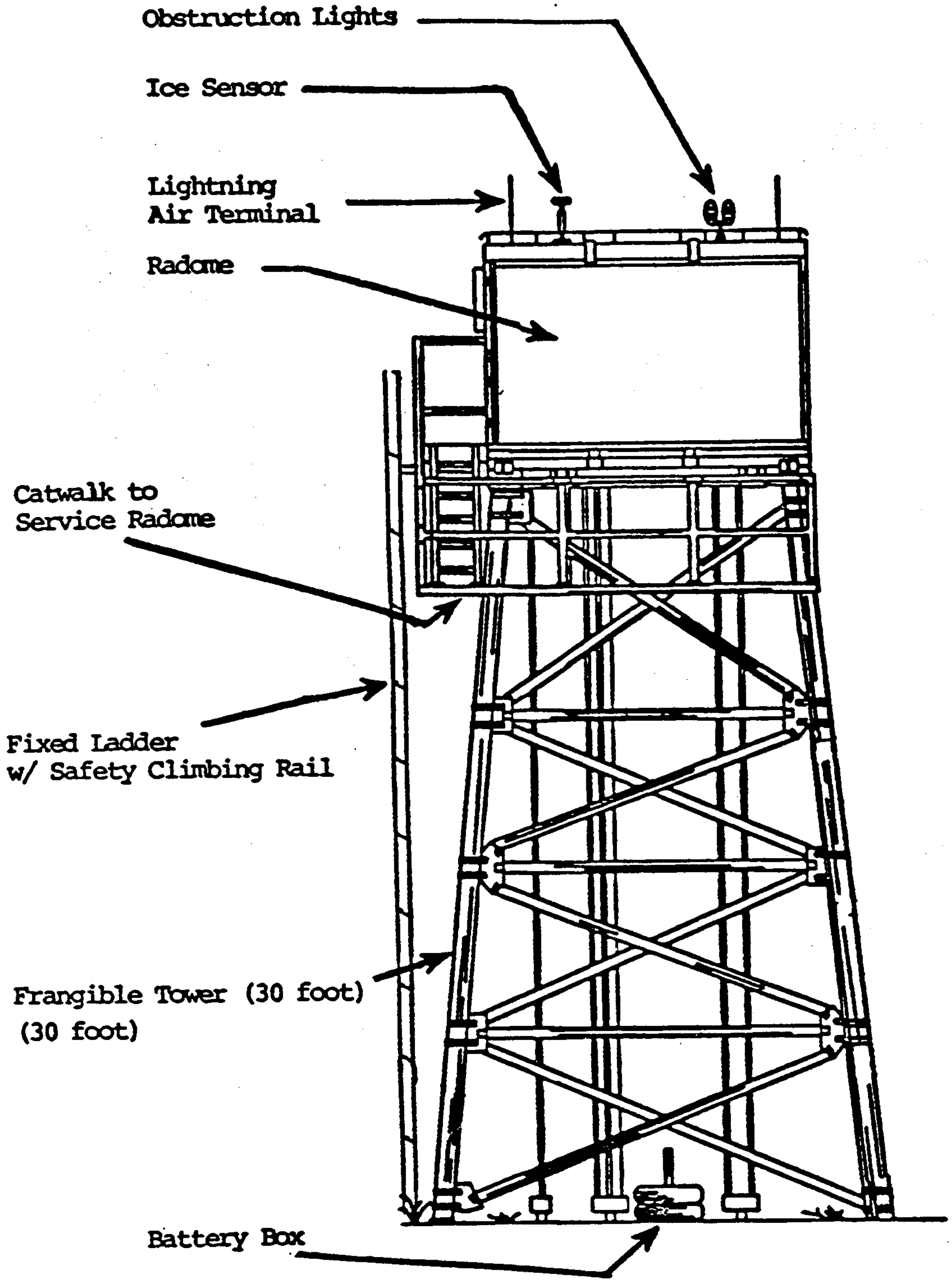
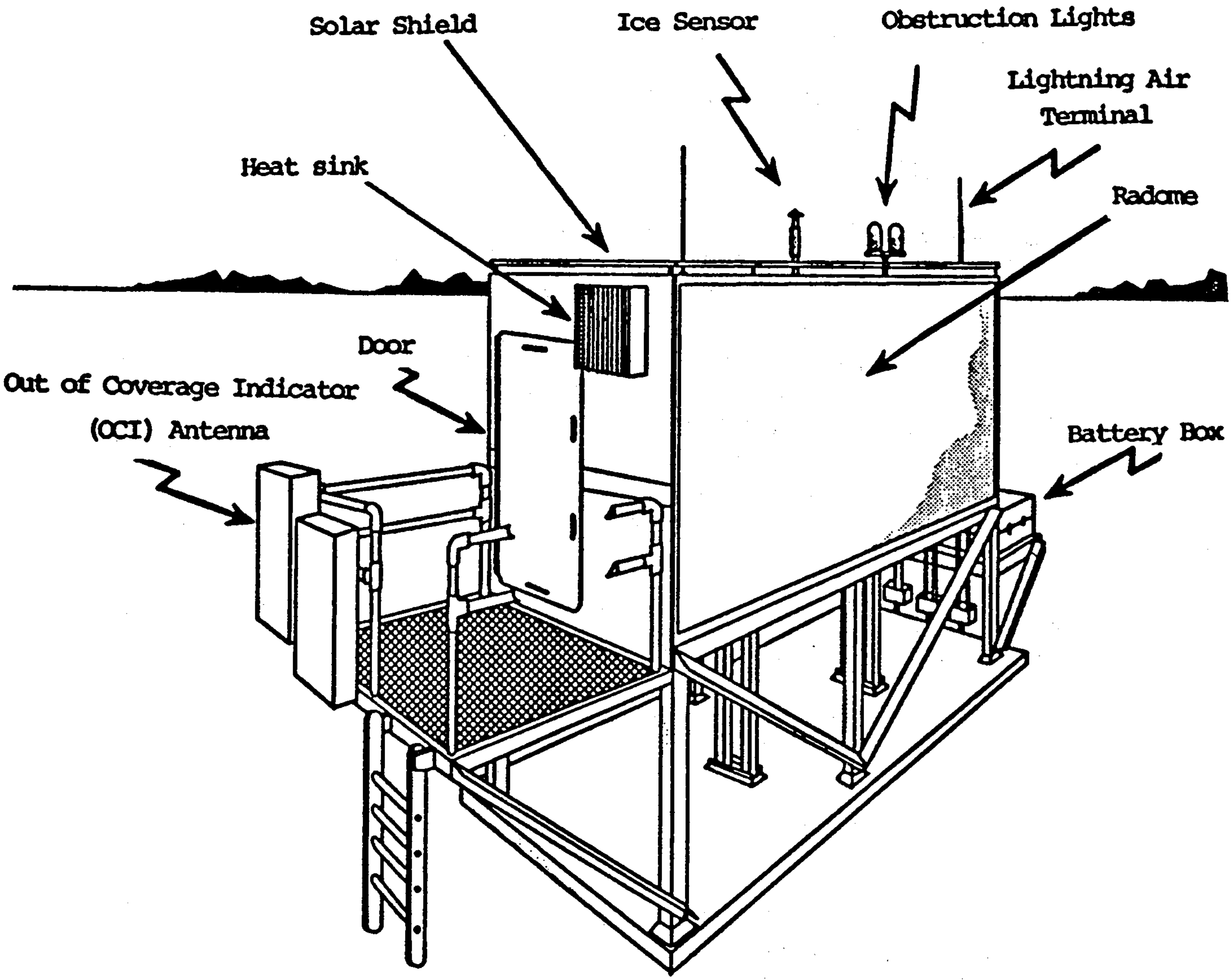


FIGURE 2-3. 1-DEGREE BEAMWIDTH AZIMUTH EQUIPMENT
(PEDESTAL MOUNT SHOWN)



A typical AZ antenna's height (excluding the pedestal) is 8 feet and its phase center height above the pedestal is 4 feet. All AZ antennas phase centers are independent of beamwidth.

(2) Precision Distance Measuring Equipment (DME/P).

(a) DME/P transponder.

(b) DME/P executive monitor.

(c) A set of cables, waveguides, connectors, and fittings.

(3) Equipment maintenance monitor.

(4) Station power/batteries.

b. Proportional Coverage. Lateral proportional coverage is normally limited to ±40 degrees. For sites with aircraft approach profiles requiring broad or one-sided coverage, ±60 degrees lateral proportional coverage may be appropriate. For sites with large lateral reflectors which cause multipath, the AZ can be operated in the high rate mode, thereby reducing multipath effects. In addition, to reduce the illumination of signal-reflecting objects, the AZ antenna proportional guidance sector is adjustable in small increments so as to provide selectable proportional guidance sectors from a minimum of 10 degrees to the limit of scan, independently on either side of antenna boresight. However, when the scan limit configuration is such that a proportional sector of at least ±40 degrees cannot be provided, clearance signals are required such that a guidance sector of at least ±40 degrees results.

c. Beamwidth Selection. The choice of AZ antenna beamwidth is mainly a function of the distance between the AZ antenna and the runway threshold.

(1) Typically, a 1-degree beamwidth antenna is used for runways of length 10,000 feet or greater.

(2) Typically, a 2-degree beamwidth is used for runways shorter than 10,000 feet.

(3) In cases where multipath reflectors present a problem, the runway should be modeled by the procedures given in chapter 6. The 1-degree option may be selected on runways shorter than 10,000 feet if the multipath environment is severe.

(4) The 3-degree beamwidth antenna is a special option used for heliport sites and for very short reflection-free airport runways.

202. APPROACH EL STATION. The approach EL station may be located on either side of the runway centerline (see figure 2-4). The function of this station is to provide vertical guidance to the aircraft on approach.

a. Station Components.

(1) EL equipment.

(a) EL equipment electronics.

(b) EL executive monitor.

(c) A set of cables, waveguides, connectors, and fittings.

(d) One of the following EL antenna options.

1 One and a half-degree beamwidth, +0.9 to +15 degrees vertical proportional coverage.

2 One-degree beamwidth, +0.9 to +15 degrees vertical proportional coverage.

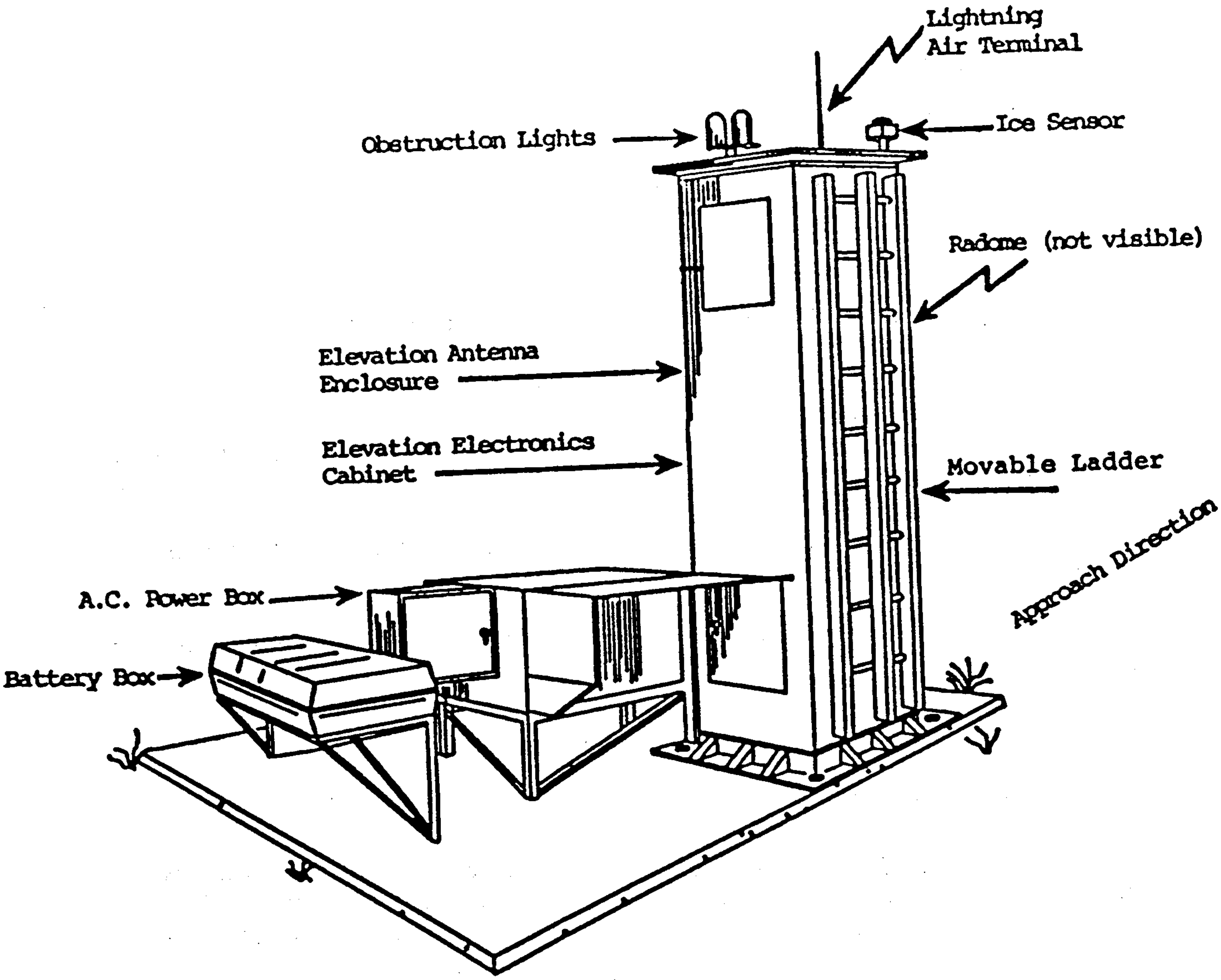
3 Two-degree beamwidth, +0.9 to +15 degrees vertical proportional coverage.

(2) Equipment maintenance monitor.

(3) Station power.

b. Elevation Antenna Beamwidth. The 1.5 degree EL antenna beamwidth is normally used at typical sites. If the approach course contains rising terrain and/or large lateral reflectors, the 1-degree beamwidth option may be required. The lower proportional guidance limit is adjustable in small increments from at least +2 degrees to -1.5 degrees. Zero degrees is defined by the horizontal plane containing the antenna phase center. The 2-degree beamwidth EL antenna is a special option used at heliport sites.

FIGURE 2-4. APPROACH ELEVATION EQUIPMENT



c. Antenna Options Table. Table 2-1 lists combinations of the AZ and EL options according to the types defined in the initial production contract.

203. REMOTE CONTROL AND STATUS UNIT (RCSU). The RCSU will be installed in the controlling facility and is interfaced with the RCSU Electronics Assembly (RCSU EA). The RCSU EA is usually located in the maintenance area and interfaces the RCSU with the MLS. In addition, there may be up to two Remote Status Units (RSU) installed at other monitoring locations. The RCSU contains controls for shutdown and restart, as well as visual and aural indications for MLS alarms and alerts.

204. REMOTE STATUS UNIT. Each RSU to be installed in other than the controlling facility provides status indications for the ground equipment and indications for alarm and alert conditions.

SECTION 2. SIGNAL FORMAT

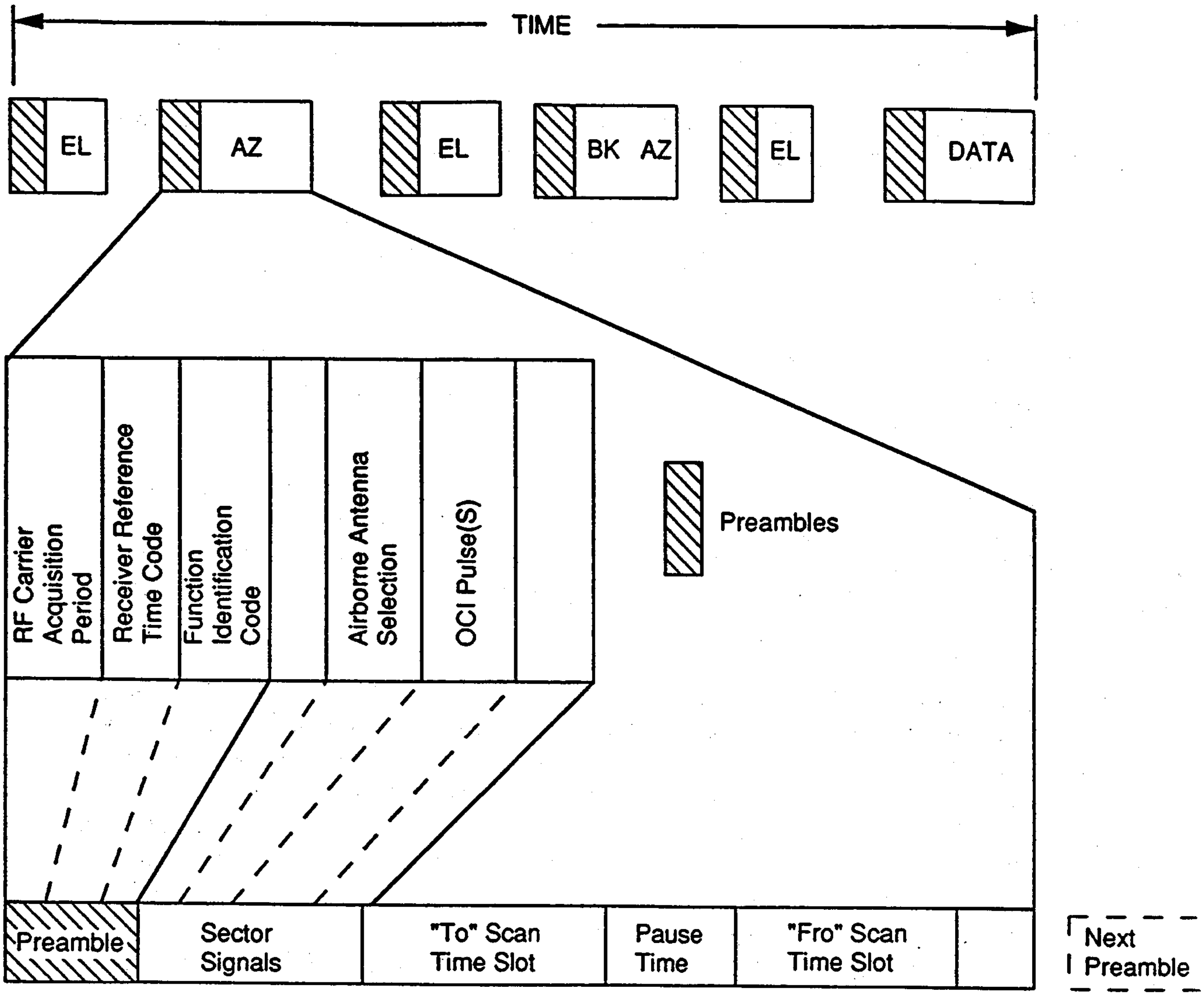
205. SIGNAL FORMAT. The three angle guidance signals (AZ, Back Azimuth (BAZ), and EL) and the data word functions are time multiplexed on a single frequency channel, selected from 200 frequency channels in the C-band 5031 to 5090.7 MHz. The signal format for angle guidance functions is shown in figure 2-5. Each signal is transmitted in its own time slot and is synchronized so it does not overlap the other signals. Since the AZ, BAZ, and EL angle guidance signals as well as the data signals are transmitted on the same frequency, a sequencing of functions is required. The AZ, BAZ, EL, and data functions are sequenced in a jittered format to prevent the functions from being repeated at regular intervals thus eliminating possible synchronous errors. In normal sequencing, the EL function is presented 39 times a second, the AZ function 13 times a second and BAZ function 6 times a second. In the high rate AZ sequence, the AZ function is provided 39 times a second. The data words are transmitted during open time periods at various rates. Additionally, range information is provided by the DME/P and is transmitted on a paired frequency from 979 to 1213 MHz.

206. GUIDANCE FUNCTION FORMATS. AZ, BAZ, and EL angle guidance information is derived utilizing the time reference scanning-beam (TRSB) method. In this method, a narrow beam is scanned in the coverage area illuminating the aircraft with a "TO"

TABLE 2-1. SYSTEM CONFIGURATIONS

TYPE	Azimuth Guidance		Elevation Guidance	
	Beamwidth	Scan Angle	Beamwidth	Scan Angle
TYPE I	2°	±40°	1.5°	0.9° to 15°
TYPE II	2°	±40°	1°	0.9° to 15°
TYPE III	1°	±40°	1.5°	0.9° to 15°
TYPE IV	1°	±40°	1°	0.9° to 15°
TYPE VI	1°	±60°	1°	0.9° to 15°
TYPE VII	3°	±40°	2°	0.9° to 15°

FIGURE 2-5. FORMAT FOR THE ANGLE GUIDANCE FUNCTIONS



scan followed by the return of the beam illuminating the aircraft with a "FRO" scan. The time difference between illuminations allows the aircraft receiver to calculate an angle. The format of the angle guidance signals is as follows:

a. Preamble. The preamble is radiated via a data antenna throughout the coverage sector and contains (1) an RF carrier acquisition period, (2) a receiver reference time code which is a Barker code that allows the aircraft receiver to establish a reference time, and (3) a function identification code which identifies whether the function is AZ, BAZ, or EL.

b. Sector Signals. The sector signals, except for the out of coverage (OCI) pulses, are also radiated via the data antenna throughout the coverage sector.

(1) Airborne antenna selection signal which is a constant amplitude signal utilized in the aircraft for comparing the signal strengths from various aircraft mounted antennas (AZ function only)

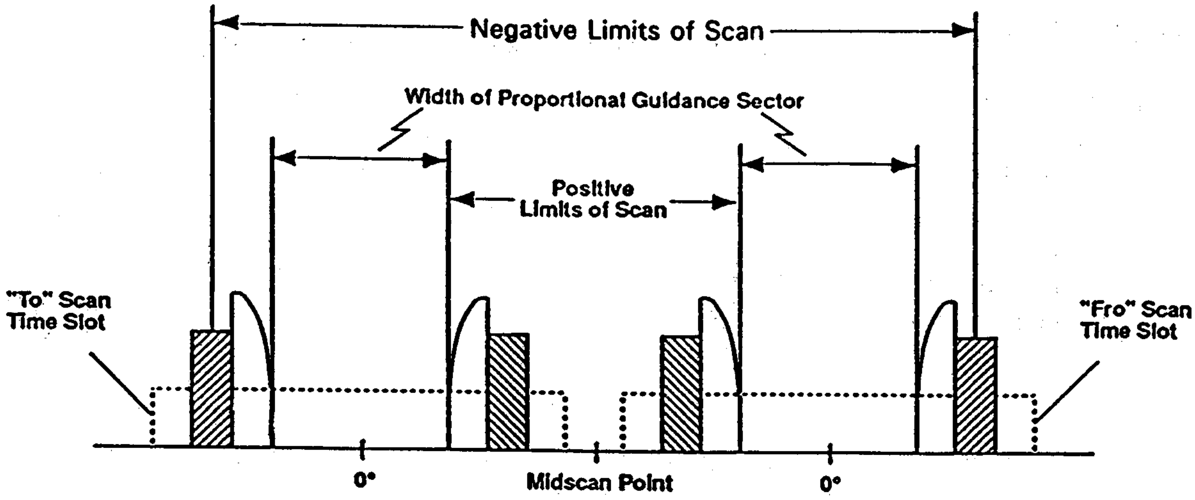
(2) The OCI pulses are radiated via separate directional type antennas for the purpose of flagging the aircraft receiver in areas of unwanted reflected signals in areas outside of proportional coverage.

c. Scanning Beams. The scanning beams, which are shown in figures 2-9 and 2-12, are received by the aircraft as the "TO" scan and "FRO" scan. The aircraft's avionics utilizes this information to calculate the angle to the aircraft receiver. The scanning beam is formed by a multi-element phased array and scans the entire area of proportional coverage. The concept of angular measurement is discussed later.

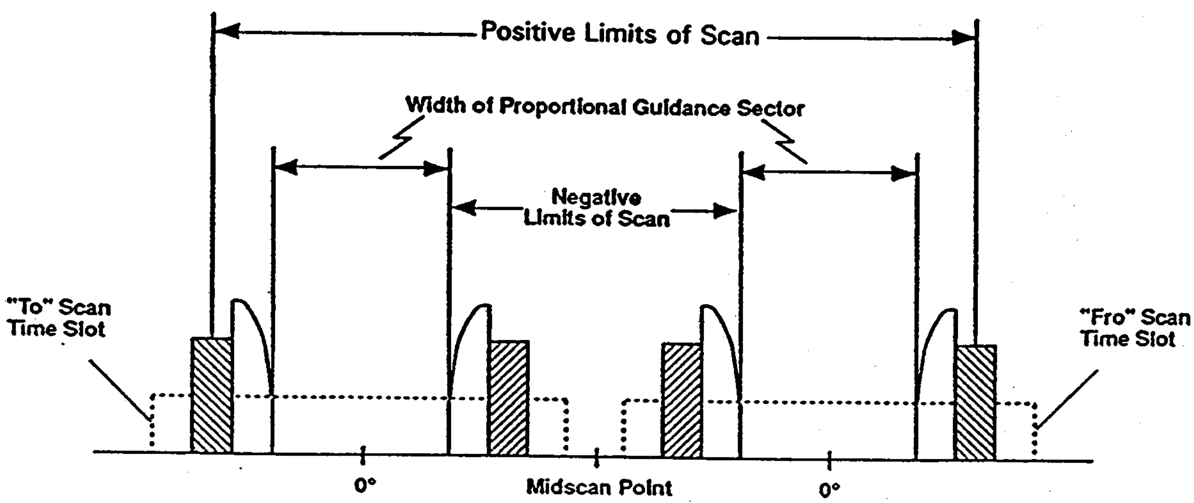
d. Clearance Pulses. If the proportional coverage provided by the "TO/FRO" scan is less than the required coverage limits, then clearance signals provide the additional coverage. One method of providing clearance signals is the radiation of pulses via a separate pair of directional antennas in the format as shown in figure 2-6. The clearance pulses are transmitted in the AZ scan time slot just prior to the start of the "TO" scan and just after the stop of the "FRO" scan. Within the clearance sectors, the fly left/right clearance guidance signal must exceed the scanning beam sidelobes and all other guidance and OCI signals by a least 5 dB. A second method is by scanning beyond the defined proportional guidance sector. Signals decoded outside of this sector will be treated as clearance by the receiver.

207. DATA FORMATS. In addition to the angle guidance signals, additional information required by the aircraft receiver is linked to the aircraft via the azimuth data antenna

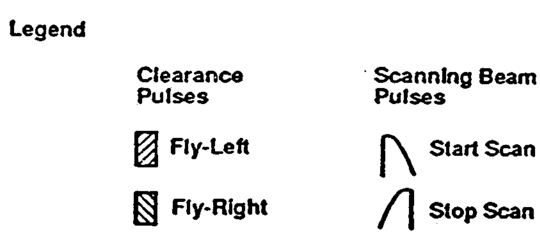
FIGURE 2-6. CLEARANCE PULSE TIMING SCHEME



(a) APPROACH AZIMUTH



(b) BACK AZIMUTH



throughout the coverage sector. The data is transmitted as digitally phase shifted keying (DPSK) at 15,625 bits per second, a change of 180 degrees in RF phase indicates a "one", no change is a "zero".

a. Basic Data. The six basic data words are 32 bit words consisting of a function preamble (12 bits), data transmission (18 bits), and parity (2 bits) as shown in figure 2-7. The actual content of the basic data words (BDW) are shown in the data transmission section.

b. Auxiliary Data. The auxiliary data words are 76 bit words consisting of a function preamble (12 bits), an address (8 bits), data transmission (49 bits), and parity (7 bits) as shown in figure 2-8.

SECTION 3. DATA TRANSMISSION

208. INCLUDED DATA. As stated previously, the AZ and EL stations radiate basic and auxiliary data to the airborne receiver via the DPSK data antennas.

a. Basic Data Words (BDW). These data words contain the following information used for approach computations:

BDW 1: AZ to threshold distance, AZ proportional coverage limits, and clearance signal type.

BDW 2: Minimum EL glidepath, BAZ status, DME status, AZ status, and EL status.

BDW 3: AZ beamwidth, EL beamwidth, and DME offset distance.

BDW 4: AZ magnetic orientation and BAZ magnetic orientation.

BDW 5: BAZ proportional coverage limits and BAZ beamwidth.

BDW 6: MLS ground equipment identification.

b. Auxiliary Data Words. The auxiliary data words will contain ground equipment siting information the aircraft receiver will utilize during curved and segmented approaches.

FIGURE 2-7. BASIC DATA ORGANIZATION

	PREAMBLE (I_1 - I_{12})		DATA TRANSMISSION (I_{13} - I_{30})		PARITY (I_{31} - I_{32})	
CLOCK PULSE	0	24	25	42	43	44

FIGURE 2-8. AUXILIARY DATA WORD ORGANIZATION

PREAMBLE (I_1 - I_{12})	ADDRESS (I_{13} - I_{20})	DATA (I_{21} - I_{69})	PARITY (I_{70} - I_{76})

SECTION 4. ANGULAR MEASUREMENT CONCEPT

209. CALCULATING ANGULAR POSITION. Angular position, either EL or AZ, is determined by the amount of time elapsed between the received "TO" and "FRO" scanning beam main lobes. Angular position is calculated by the airborne receiver as follows:

$$\theta = (T_0 - t)V/2$$

Where:

θ = AZ or EL angle in degrees.

T_0 = Time separation in microseconds between "TO" and "FRO" beam centers corresponding to zero degrees.

t = Time separation in microseconds between "TO" and "FRO" beam centers.

V = Scan velocity scaling constant in degrees per microsecond.

Table 2-2 lists values for these parameters.

210. AZIMUTH. The AZ antenna generates a narrow, vertical, fan-shaped beam which electronically scans across its coverage area (see figure 2-9). The AZ scanning convention is shown in figure 2-10. As viewed from above the AZ antenna, the "TO" scan is in the clockwise direction and the "FRO" scan is in the counter-clockwise direction. An illustrated example is shown in figure 2-11.

211. ELEVATION. The EL antenna generates a narrow, horizontal, fan-shaped beam which electronically scans through its coverage area (see figure 2-12). The elevation scanning convention is shown in figure 2-13. The "TO" scan is upward. The "FRO" scan is downward.

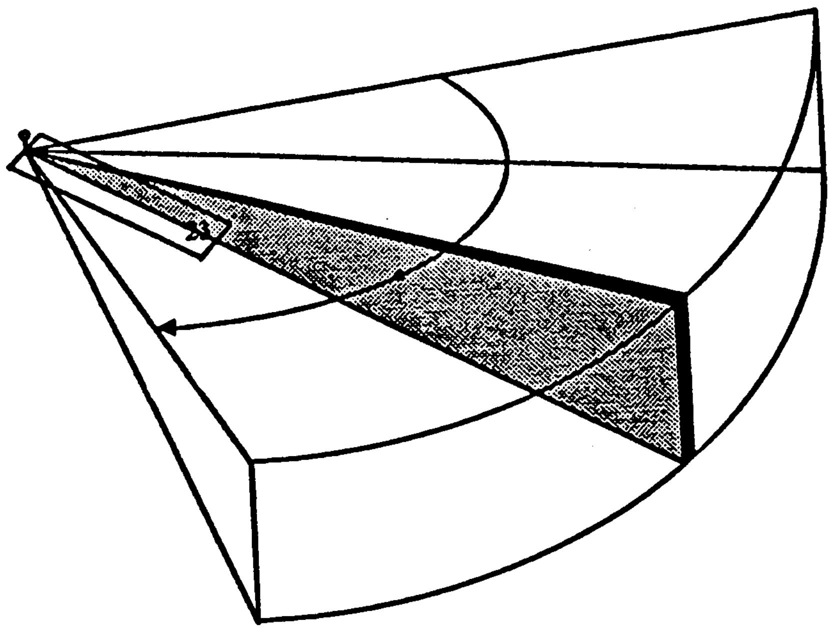
SECTION 5. FUNCTION COVERAGE REQUIREMENTS

212. OVERVIEW. This section describes the minimum volume of airspace where MLS guidance information is required. The approach coverage volumes for the AZ , EL and

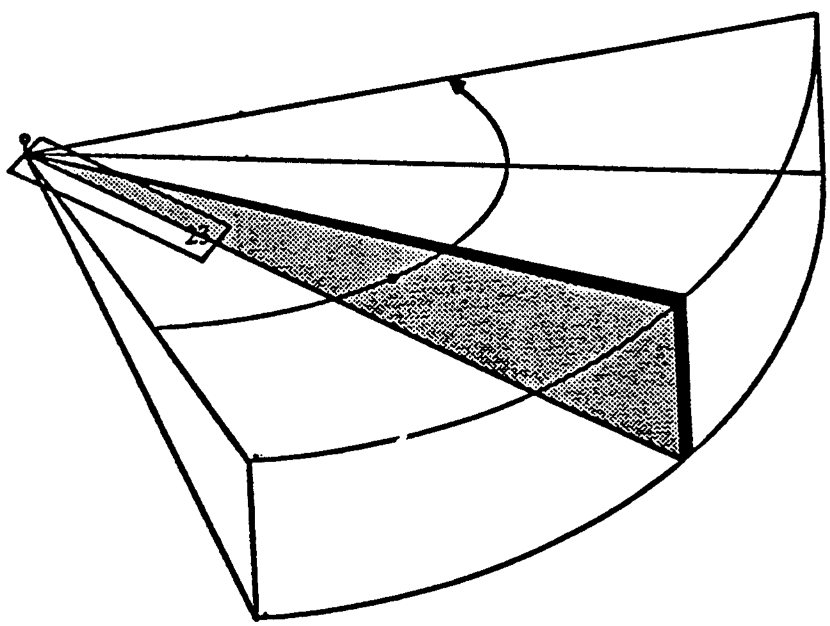
TABLE 2-2. VALUE OF ANGLE GUIDANCE PARAMETERS

Function	Maximum Scan Angle (degree)	Value of t for Maximum Scan Angle (usec)	T_0 (usec)	V (degrees/usec)
APPROACH AZIMUTH HIGH RATE	-62 to +62	13 000	6 800	+0.020
APPROACH AZIMUTH	-42 to +42	9 000	4 800	+0.020
BACK AZIMUTH	-42 to +42	9 000	4 800	- 0.020
APPROACH ELEVATION	-1.5 to +29.5	3 500	3 350	+0.020

FIGURE 2-9. AZIMUTH ANTENNA SCANNING BEAM

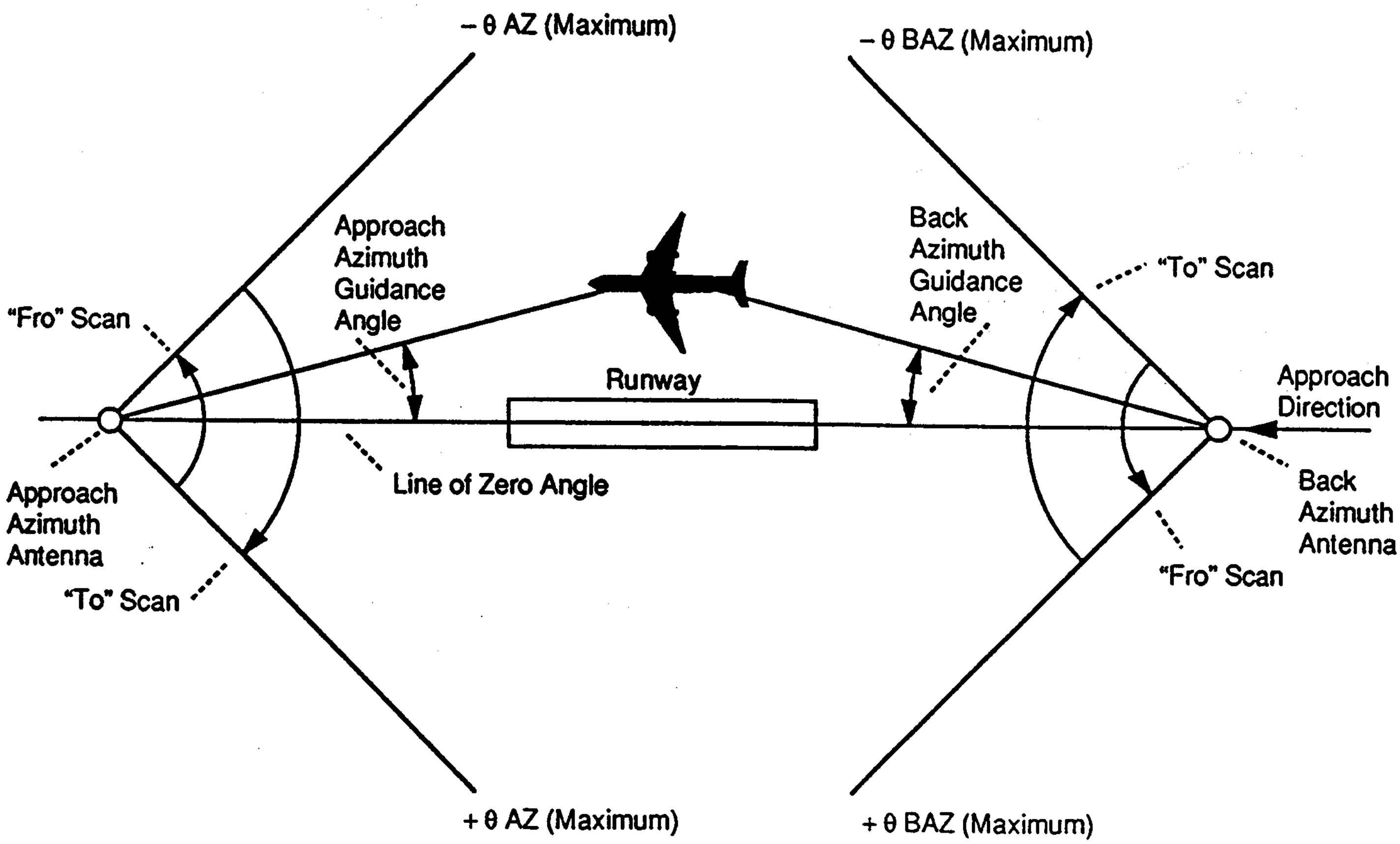


TO
SCAN



FRO
SCAN

FIGURE 2-10. AZIMUTH SCANNING CONVENTION



Note: The Approach and Back Azimuth angles are negative for the position of the aircraft shown in the figure.

FIGURE 2-11. ILLUSTRATION OF AZIMUTH SCANNING CONCEPT

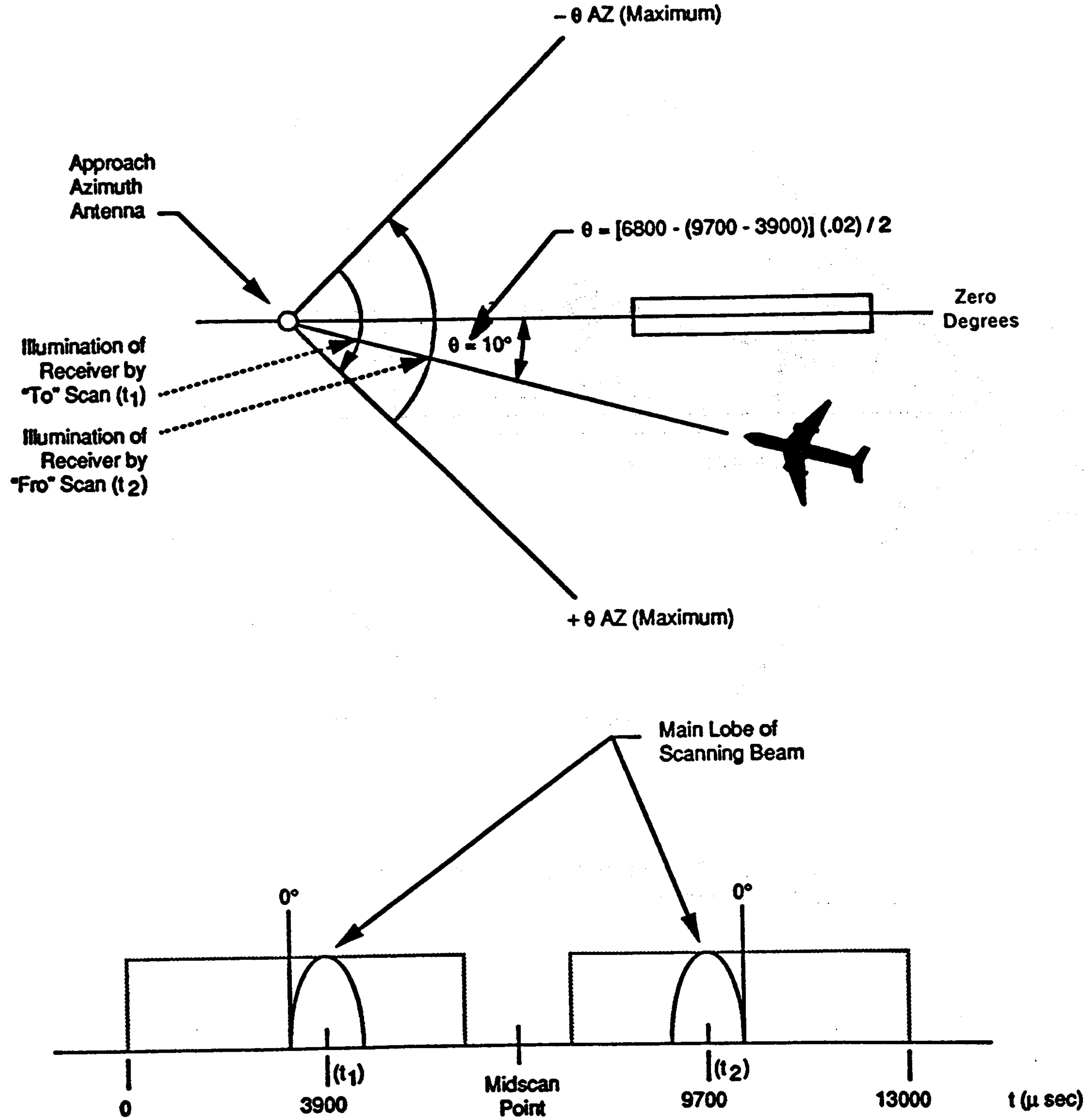
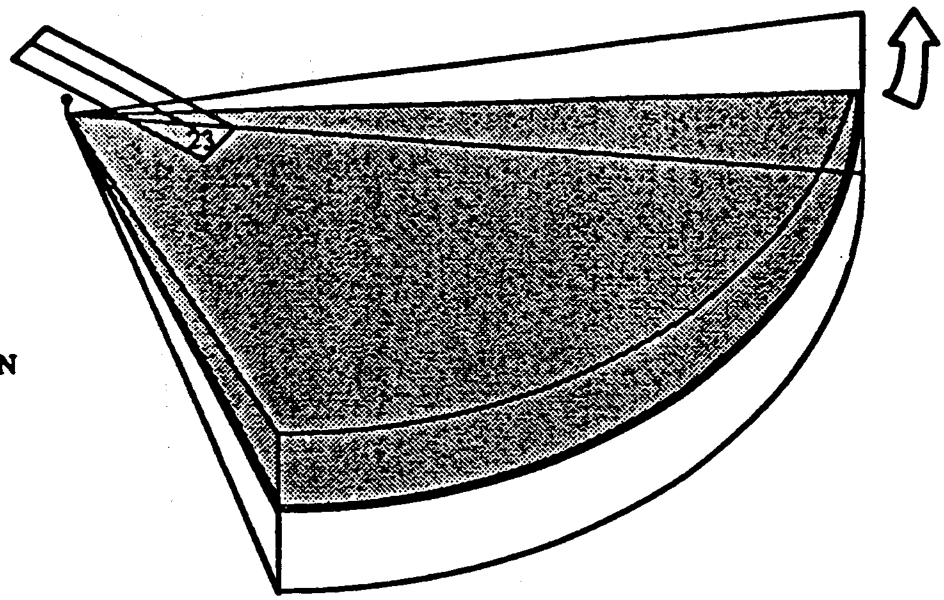


FIGURE 2-12. ELEVATION ANTENNA SCANNING BEAM

TO
SCAN



FRO
SCAN

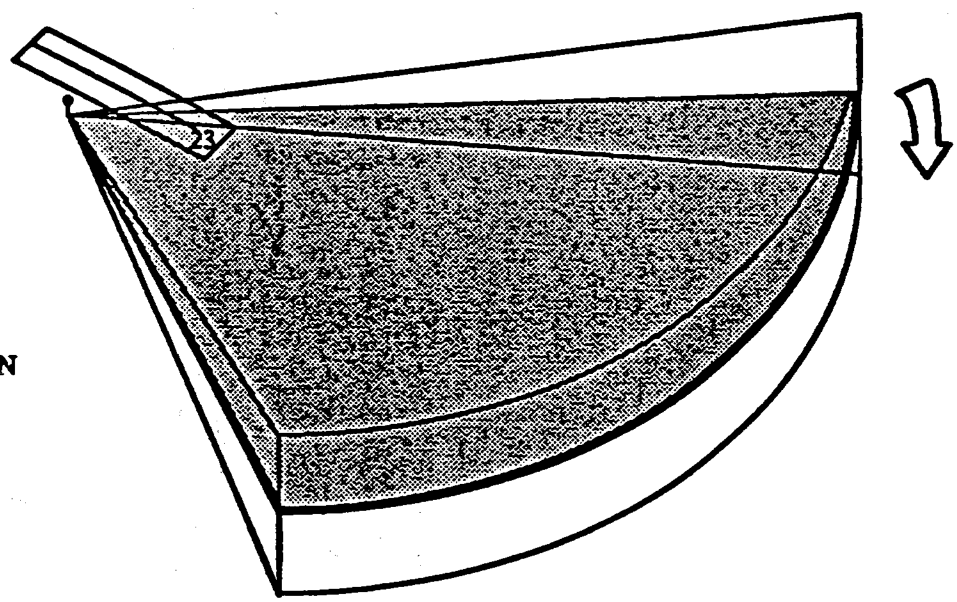
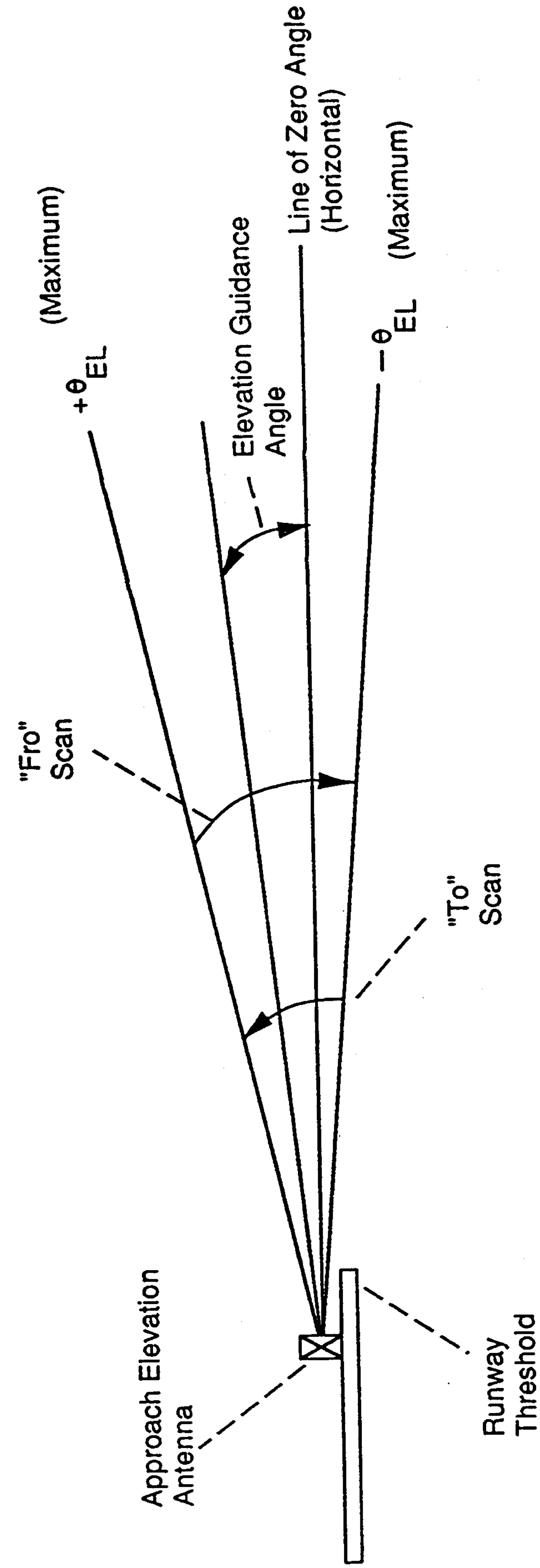


FIGURE 2-13. ELEVATION SCANNING CONVENTION



DME/P signals originate at the phase center of the antenna which radiates that function. To ensure coverage to low heights in the final approach region, the approach AZ and EL functions have minimum proportional/operational coverage sectors which originate at the MLS datum point near runway threshold. Additional coverage in the runway region is required of the approach AZ function.

213. APPROACH AZ. The approach AZ ground equipment is required to provide guidance information as illustrated in figures 2-14 and 2-15. The minimum coverage regions extend:

a. Approach Region.

(1) Laterally, within a sector of ±40 degrees which originates at the approach AZ antenna phase center. For a system providing ±60 degrees of lateral coverage, the range requirement is reduced to 16.5 nautical miles beyond the ±40 degree angular coverage.

(2) Longitudinally, from the approach AZ antenna to 22.5 nautical miles.

(3) Vertically between:

(a) A lower conical surface originating at the approach AZ antenna and inclined upward such that, at the longitudinal coverage limit, a height of 600 meters (2,000 ft) above the horizontal plane which contains the antenna phase center, is not exceeded.

(b) An upper conical surface originating at the approach AZ antenna inclined at 15 degrees above the horizontal to a height of 6,000 meters (20,000 ft).

b. Runway Region.

(1) Horizontally within a sector 45 meters (150 ft.) each side of the runway centerline beginning at the stop end and extending parallel with the runway centerline in the direction of the approach to join the minimum proportional coverage region.

FIGURE 2-14. AZIMUTH/DATA APPROACH REGION COVERAGE

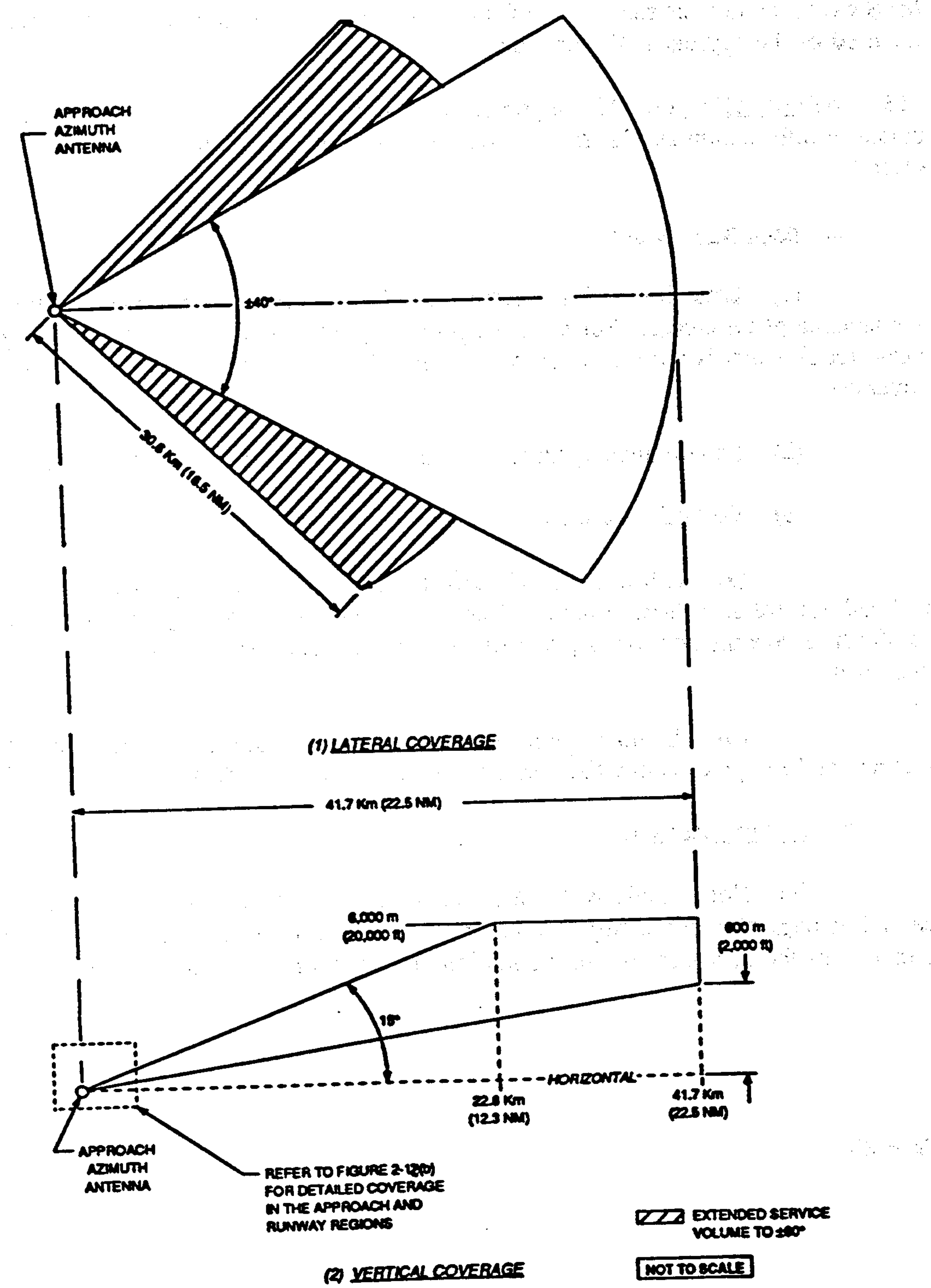
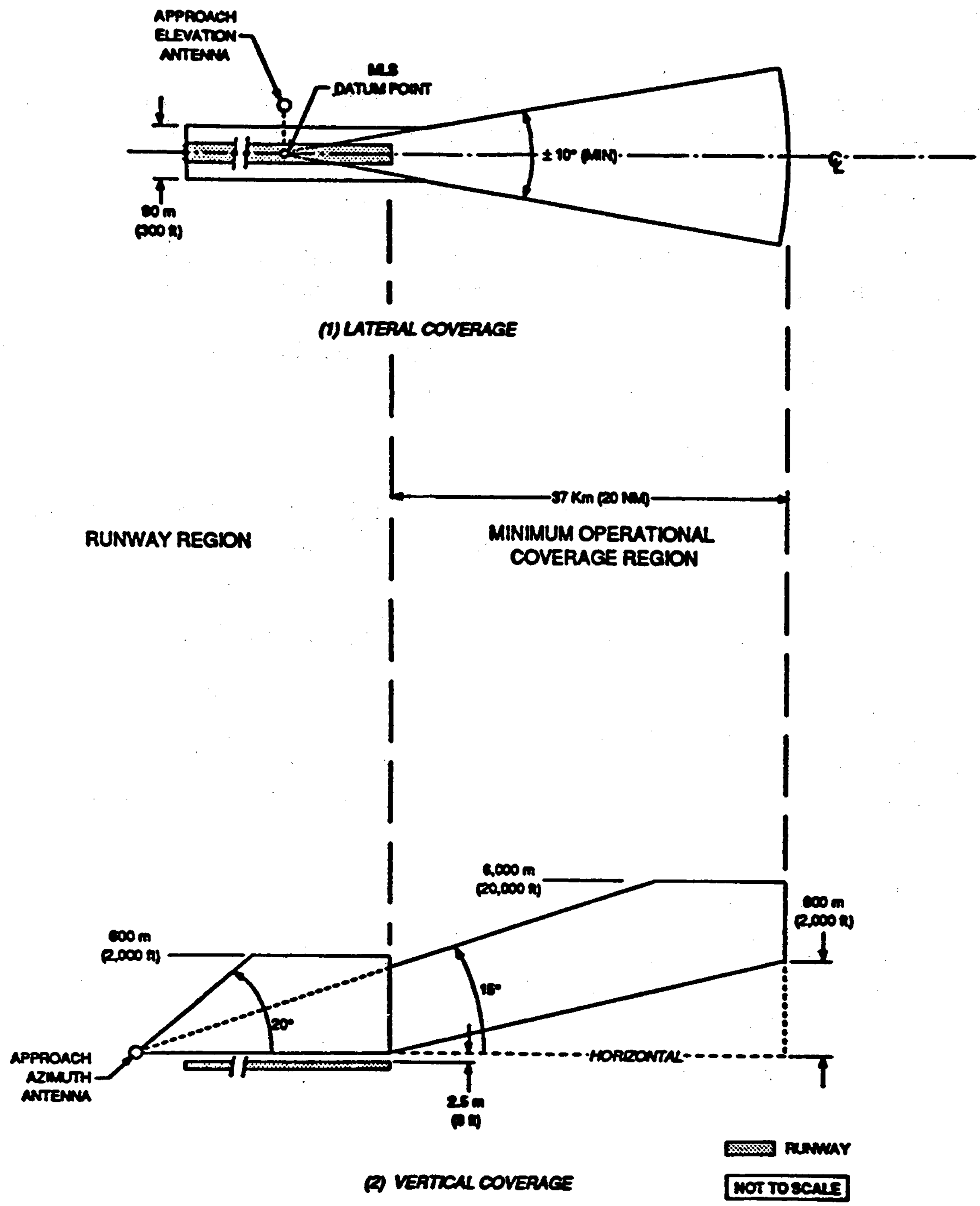


FIGURE 2-15 AZIMUTH RUNWAY REGION COVERAGE AND MINIMUM OPERATIONAL COVERAGE REGION



(2) Vertically between:

(a) A horizontal surface which is 2.5 meters (8 ft.) above the runway centerline.

(b) A conical surface originating along the centerline extended beyond the stop end of the runway which crosses the stop end at 150 meters (500 ft.) above centerline inclined at 20 degrees above the horizontal to a height of 600 meters (2,000 ft.).

c. Minimum Proportional/Operational Coverage Region.

(1) Laterally, throughout an angular sector of at least ±10 degrees about the runway centerline extended which originates at the MLS datum point.

(2) Longitudinally from the runway threshold in the direction of the approach to the longitudinal coverage limit specified in subparagraph 213a(2).

(3) Vertically, between:

(a) A lower plane which contains the line 2.5m (8 ft.) above the runway threshold and is inclined upward such that the height of the surface specified in subparagraph 213a(3)(a).

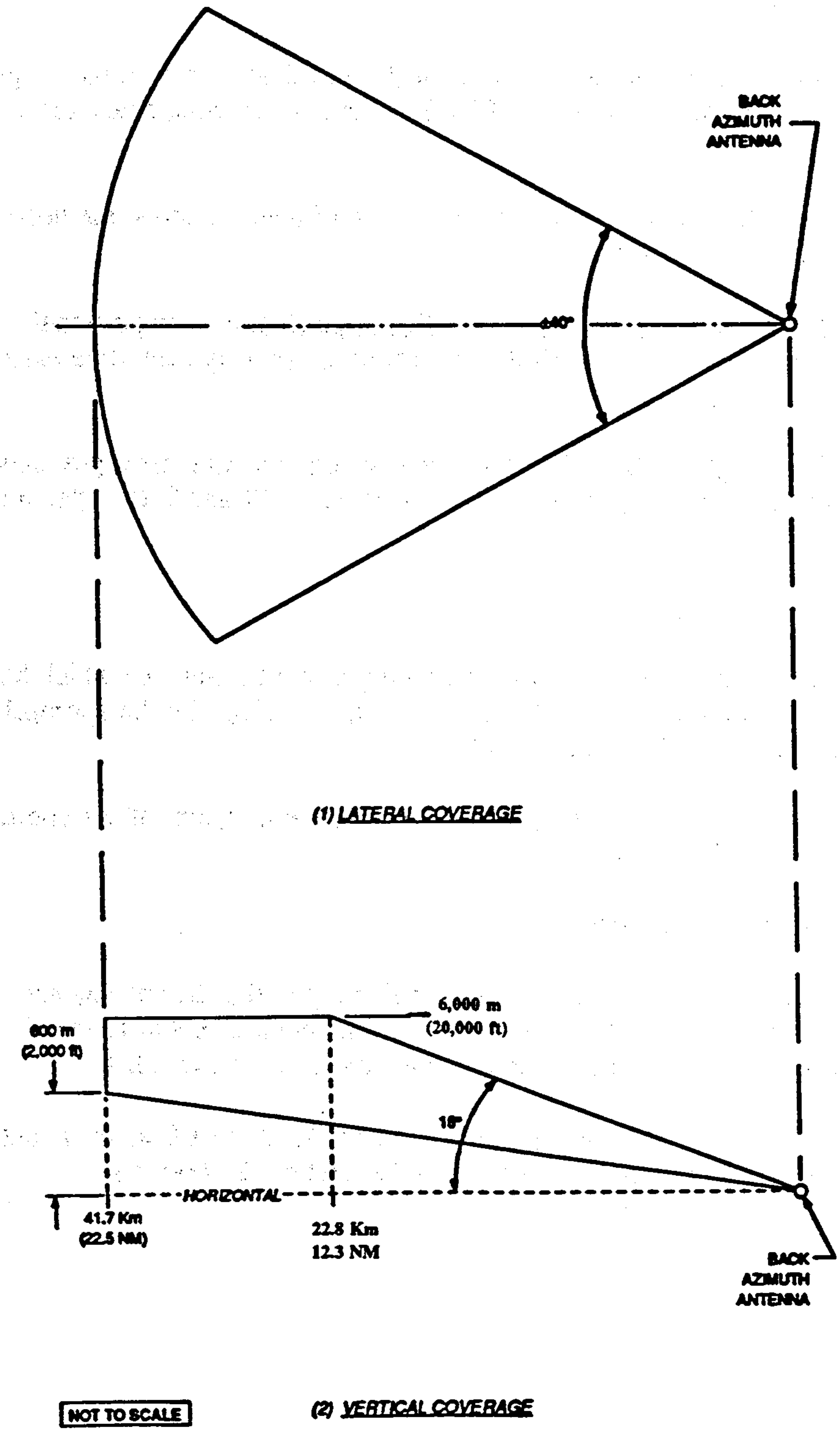
(b) The upper surface specified in subparagraph 213a(3)(b).

214. BACK AZIMUTH. If AZ guidance is desired for missed approaches and departure guidance (BAZ), it will be provided by a standard MLS AZ station located at the opposite end of the runway with its preamble and time slot changed accordingly. This BAZ will supply guidance information in the region shown in figure 2-16. The minimum guidance volume extends:

a. Missed Approach/BAZ Region.

(1) Horizontally in the BAZ region within a sector ±40 degrees about the runway centerline originating at the phase center of the BAZ antenna and extending in the direction of missed approach at least to 22.5 nautical miles.

FIGURE 2-16. BACK AZIMUTH/DATA COVERAGE



(1) LATERAL COVERAGE

(2) VERTICAL COVERAGE

(2) Vertically in the BAZ region between conical surfaces which originate at the antenna phase center of which:

(a) The lower surface is inclined upward such that, at the longitudinal coverage limit, a height of 600 meters (2,000 ft.) above the antenna phase center is not exceeded.

(b) The upper surface is inclined at 15 degrees above the horizontal to a height of 6,000 meters (20,000 ft.).

b. Minimum Proportional/Operational Coverage Region. Proportional guidance will be provided in a sector of at least ±10 degrees about the runway centerline extended in the BAZ region.

215. APPROACH ELEVATION. The approach EL ground equipment provides proportional guidance in the regions illustrated in figures 2-17 and 2-18. The minimum coverage regions extend:

a. Approach region.

(1) Laterally, within a sector originating at the EL antenna which has an angular extent at least equal to the proportional guidance sector provided by the approach AZ ground equipment at the longitudinal coverage limit.

(2) Longitudinally from the EL antenna in the direction of the approach to 20 nautical miles from threshold.

(3) Vertically between:

(a) A lower conical surface originating at the EL antenna and inclined upward such that, at the longitudinal coverage limit, a height of 600m (2,000 ft.) above the horizontal plane which contains the antenna phase center is not exceeded.

(b) An upper conical surface originating at the EL antenna and inclined 15 degrees above the horizontal up to a height of 6,000 meters (20,000 ft.).

FIGURE 2-17. ELEVATION APPROACH REGION COVERAGE

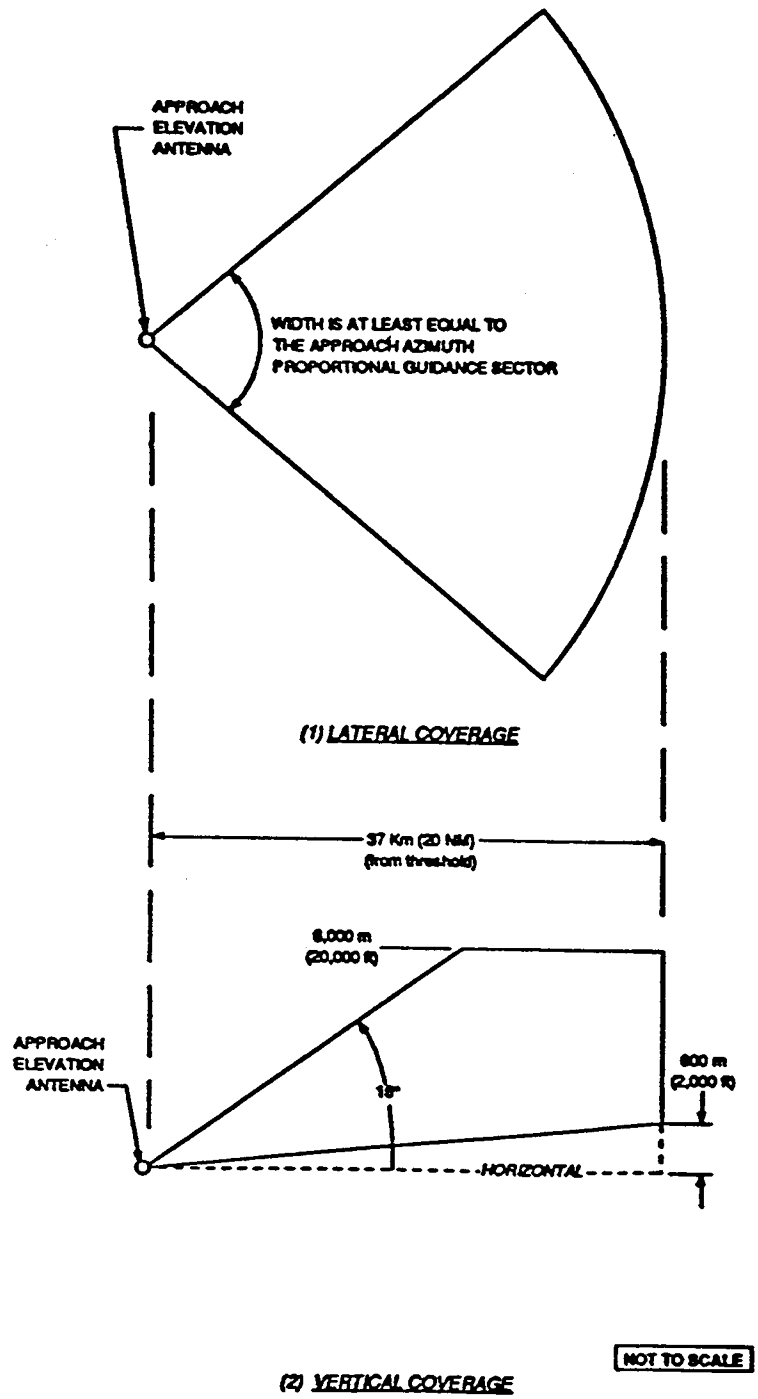
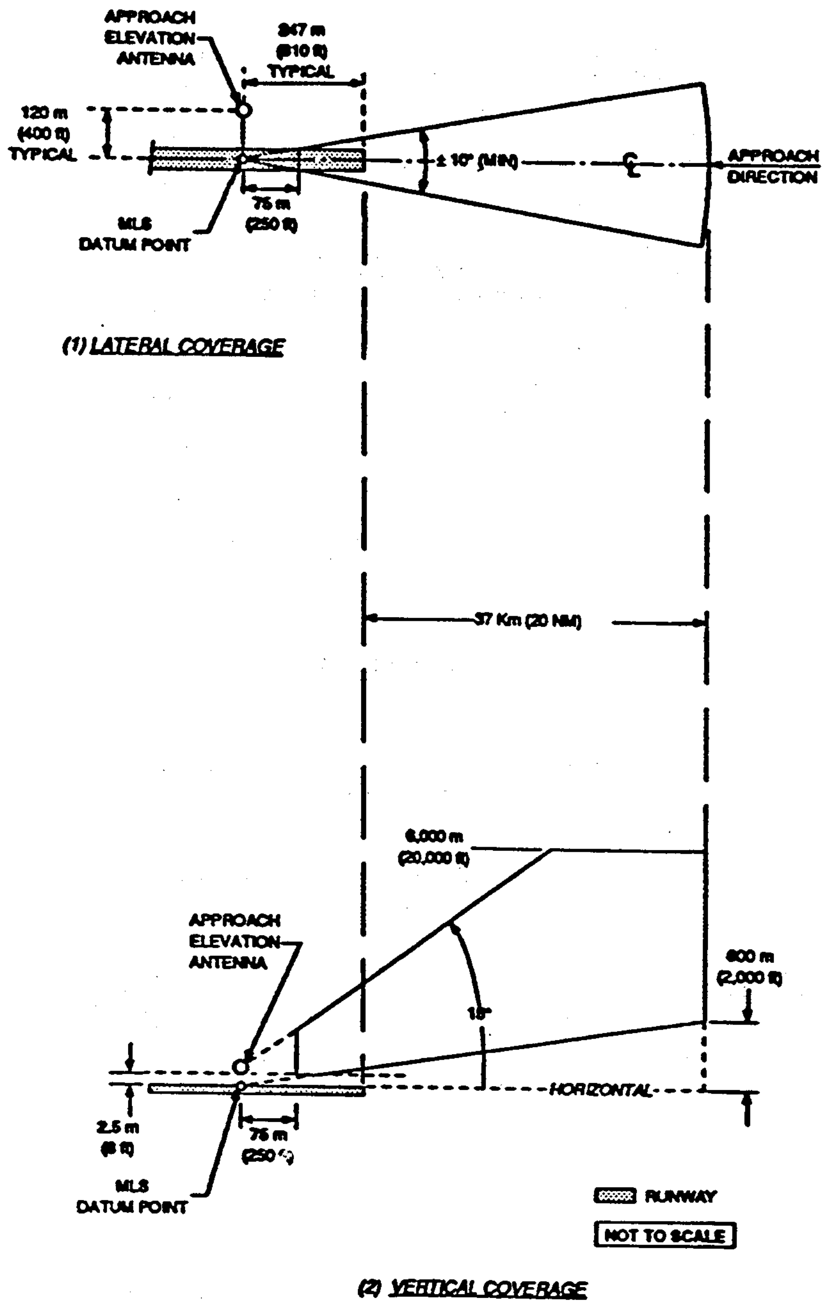


FIGURE 2-18. ELEVATION MINIMUM OPERATIONAL COVERAGE REGION



b. Minimum Operational Coverage Region.

(1) Laterally throughout an angular sector, originating at the MLS datum point, of at least ±10 degrees about the runway centerline.

(2) Longitudinally from 75m (250 ft.) before the MLS datum point in the direction of threshold to the far coverage limit specified in subparagraph 215a(2).

(3) Vertically, between the upper surface specified in subparagraph 215a(3)(b) and the higher of:

(a) A surface which is the locus of points 2.5m (8 ft.) above the runway.

(b) A plane, which is parallel to threshold, originating at the MLS datum point and inclined upward such that, at the longitudinal coverage limit, the height of the surface specified in subparagraph 215a(3)(a) is not exceeded.

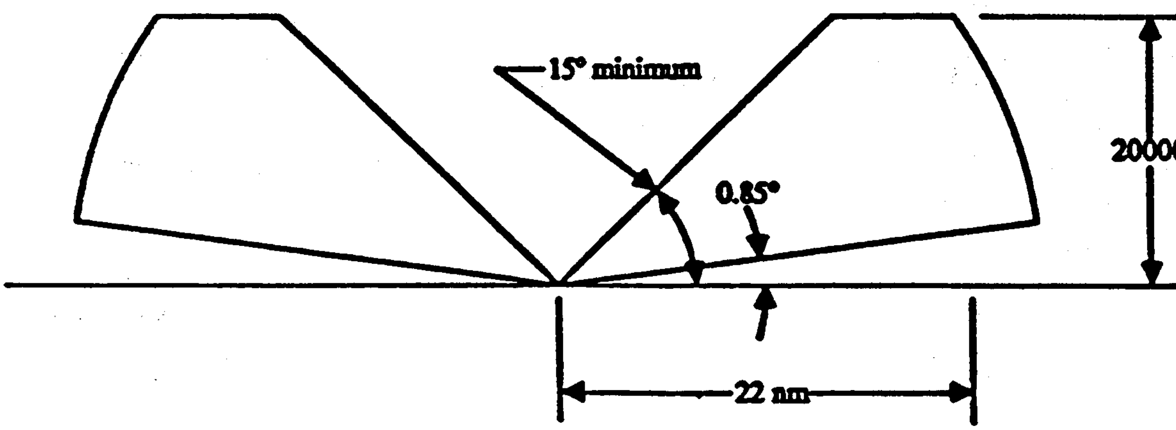
216. DATA COVERAGE. Basic and auxiliary data will be transmitted throughout the approach AZ and BAZ coverage regions.

217. DME/P. DME/P coverage will be as shown in figure 2-19. Coverage will be provided at all azimuth angles and angles of elevation between +0.85 degrees to a minimum of +15 degrees relative to the DME/P antenna phase center and up to heights of at least 20,000 ft.

SECTION 6. DUAL MODE AZIMUTH CAPABILITY

218. FUNCTIONS. The MLS AZ station is capable of supplying either the approach or BAZ function. This dual capability is normally implemented when two complete sets of MLS ground equipment are used to serve opposite ends of the same runway (see figure 2-10). The BAZ feature provides departure guidance and precision missed approaches.

FIGURE 2-19. DME/P COVERAGE



NOTE: The DME/P coverage is omnidirectional in the horizontal plane

219. MODES.

a. The AZ station is operated on the same frequency when operating in the approach AZ mode or in the BAZ mode. During the transfer of modes from approach AZ to BAZ (or the reverse), there will be a period of no MLS guidance from either approach MLS for a period of nominally 20 seconds due to the interlock feature.

b. It is intended that the approach AZ station will normally operate in the high rate (i.e., 39 Hz) mode. However with the ±60 degree antenna, the AZ equipment operates in the 13 Hz rate mode. With an AZ equipment providing ±60 degree lateral coverage, the range requirement is reduced to 14 nm between 40 degrees and 60 degrees angular coverage.

c. Dual MLS systems serving each end of a runway are interlock controlled via the RCSU. The RCSU controls whether an AZ station is in the AZ or BAZ mode as well as bringing up the appropriate front approach EL station and the DME/P equipment.

d. With a single runway end installation the AZ may still be switched to BAZ to provide departure guidance.

SECTION 7. ADDITIONAL MLS CAPABILITIES

220. AUXILIARY DATA. The MLS format has provided space for the transmission of additional auxiliary data. This data may include information to conduct curved approach and departure procedures.

221. LIMITED-SCAN AZIMUTH COVERAGE. MLS can also provide nonsymmetrical AZ proportional coverage. An example of this feature is 10 degrees proportional guidance on one side of the runway and 40 degrees on the other. This feature can be used to reduce multipath reflections caused by objects close to one side of the runway without sacrificing coverage on the other. However, if proportional guidance is not provided in any sector(s) within ±40 degrees of runway centerline, clearance signals must be provided within those sector(s) unless unwanted reflection of the clearance signals occurs.

222.-299. RESERVED.

CHAPTER 3. INSTALLATION REQUIREMENTS

300. MLS POWER REQUIREMENTS.

a. Ground Equipment. All MLS ground equipment is designed to be powered from 120/240 volts, three-wire single-phase 60 Hz power. The alternating current (AC) power source will provide sufficient power to operate the MLS and simultaneously recharge the batteries to full charge from 50 percent discharge within 36 hours. Refer to the appropriate manufacturer's instruction book for power requirements.

b. Operating Voltage. The nominal operating voltage is 120 VAC, but the ground equipment is designed so that it can be powered from 102-138 VAC. Equipment requiring 240 VAC will be capable of operating on 204-276 VAC. In addition, the ground equipment will tolerate a ± 3 Hz drift from the nominal 60 Hz line frequency.

c. Batteries. The MLS ground equipment is also designed to operate from rechargeable batteries for at least 2 hours after loss of primary AC power. The system is designed so that performance will not be degraded in any way while it is operating from the battery supply. The system will operate so that loss of AC power does not result in loss of MLS ground system operation during the switch to the battery back-up system.

(1) The batteries are protected from the elements since snow or rain could cause them to fail. The battery container permits easy access to the batteries for inspection and maintenance. They are also vented to the outside of the enclosing structure.

(2) Heaters may be used inside the battery container to assure a minimum of 2 hours of normal equipment operation at low temperatures upon loss of primary power.

d. Power Requirements. The equipment loads will vary according to manufacturer. When calculating power requirements, maximum loads should be considered, including equipment startup, antenna heaters, and battery chargers. For AZ stations located in the runway safety area, power transformers will be located outside of the safety area.

e. Continuous Power Airports. Some airports are equipped with an emergency power source in the event of an areawide or catastrophic prime power failure. This power source maintains power for facilities on a selected runway, sustaining operations in Visual Flight Rules (VFR) or Instrument Flight Rules (IFR) conditions. Continuous power airports are identified in the latest edition of Order 6030.20, Electrical Power Policy.

301. EQUIPMENT AND STRUCTURE REQUIREMENTS. The electronic equipment contained in the enclosures is designed to operate normally when exposed to temperatures of -50 to +50 degrees centigrade and humidities of 5 percent to 90 percent.

a. All outside equipment, electronic or mechanical, will also function within tolerance at temperatures of -50 to +50 degrees centigrade. The ground equipment will continue to operate within monitor tolerance when exposed to wind velocities of 70 knots in any direction in which the perpendicular component of the wind with respect to the runway centerline is not greater than 35 knots. The ground equipment will resist wind velocities of 87 knots in any direction without suffering structural or functional damage.

b. All outside structures will be capable of withstanding hailstones up to 0.5 inch in diameter and a snow loading of 40 pounds per square foot.

302. SITE EVALUATION. While evaluating the MLS siting environment, special attention should be paid to the location of trees, buildings, and any large objects which might cause multipath (signal reflections) or shadowing (signal blockage) problems. If the airport environment contains runway humps or uneven ground, equipment towers may be necessary to assure adequate signal coverage at threshold. Specific analysis information is given in chapter 6.

a. It has been shown that interference from power lines, fences, and approach light systems in the far field of the antennas will be minimal at the MLS frequency. Unless these structures are unusually large or consist of densely spaced conductors, they will not be of concern.

b. MLS normally does not require grading and site preparation of the local terrain. However, some grading for the equipment foundation may be required.

c. Other site dependent problems that must be assessed include soil bearing strength, site access for installation and maintenance, and snow accumulation.

303. INTERSTATION COMMUNICATIONS REQUIREMENTS.

a. Communications. A communications link must be provided between all MLS ground equipment serving a particular runway (or each end of the same runway if dual MLS systems are installed), the RCSU, the RSU, and the Remote Maintenance Monitor (RMMS). Communications are required for three purposes:

(1) The ground equipment transmissions require synchronization to prevent an overlapping of functions.

(2) Equipment status is provided via the communications link to the remote control and/or status units.

(3) Equipment status and data is provided to the RMMS.

b. The Communications Link. This link may be provided through any of these three media: wire cables, fiber optic cables, or radio link. If wire cables already exist, are of suitable quality for the MLS data transmissions, and have a useful life of at least 10 years remaining, they should be utilized where practical. New fiber optics cable should be installed if it is determined that the existing cable does not have a useful life of at least 10 years remaining (the manufacturers instruction book should be used to determine if the existing cable is of suitable type for the communications link). Radio link should be used only as a last resort if a wire or fiber installation would be too costly or otherwise impractical.

304. REMOTE CONTROL AND STATUS UNIT. The RCSU consists of two units.

a. RCSU Control and Display Panel. This panel is installed in the local air traffic control (ATC) facility (control tower) if one exists. If not, the RCSU should be placed in a location where there are communications with the nearest ATC facility.

b. RCSU Electronics Unit. This unit sends information to the display panel and is the interface point for the RMMS. It should be installed in a location with easy access by maintenance personnel.

c. Dual MLS Operation. In the situation where MLS equipment is installed to serve both ends of a runway, a single RCSU (consisting of both electronics and display) will control both systems.

305. REMOTE STATUS UNIT. The RSU is a status panel that is a slave to the RCSU. It can be located at any location where the status of the MLS is of interest. Up to two RSU's may be installed with each RCSU.

306.-399. RESERVED.

CHAPTER 4. BASIC SITING CONCEPTS

400. PREPARATION OF DATA. Before the installation of any MLS equipment, data are to be obtained to permit evaluation of the runway(s) to be serviced as well as the surrounding area. Those consulted should include airport officials, Flight Standards, Air Traffic, Airports, and Airway Facilities. These consultations will provide information concerning such topics as:

a. Airport Clearance Charts (Department of Commerce publication). Siting considerations may dictate equipment placement near obstruction clearance boundaries.

b. United States Geological Survey (USGS) topographical charts of the airport area and full service coverage area for the MLS.

c. Airport Layout Plan which shows surveys including runways to be serviced with MLS, their lengths and profiles (detailed enough to accurately identify runway humps).

d. Description of existing ATC facilities, navigational aids (NAVAIDS) lighting and power sources.

e. Airport conduit and cable information.

f. Ground traffic patterns. Ground traffic is not permitted within the critical areas.

g. Run-up and jet blast areas.

h. Determination of the approach reference datum (ARD) and minimum glidepath.

i. MLS type proposed and equipment characteristics pertinent to siting.

j. Airport property lines.

k. U.S. Instrument Approach Procedures defining existing approach procedures to the airport and identifying obstacles in the terminal area.

l. Noise abatement regions, procedures, and plans.

m. Restricted airspace.

n. Air Traffic requirements for proportional coverage outside the normal coverage areas because of approach design.

o. Existing and future traffic patterns.

p. Any required alteration to proposed approach paths. Proper siting may require a change in some proposed approach paths.

q. Obstacle free zones and runway safety areas.

401. AIR TRAFFIC PLANNING INPUT.

a. Utilization Planning. To take advantage of the capabilities of the MLS, it is important that siting personnel work closely with air traffic planners. A well developed utilization plan is required to take full advantage of MLS capabilities within the Air Traffic and Flight Standards organizations. The Air Traffic organization has developed a facility analysis guide Order 7110.96, Air Traffic Control Facility Analysis Program for the Microwave Landing System, which can be used to aid facility managers in assuring that all known considerations have been examined when planning.

b. Staff Study. The result of the application of this analysis guide is a staff study which details the intended use and locations of MLS equipment. Recommendations made in this study include facility(ies) or runway(s) to be equipped, what types of approach profiles are desired, deviations required from the standard ± 40 degree AZ coverage, and how the AZ coverage should be oriented. The AZ station antenna may be skewed to provide more proportional coverage on one side of the runway centerline. At present, the siting criteria to skew the AZ antenna has not been developed.

402. CRITICAL AREAS. Critical areas are regions around the MLS stations wherein objects, vehicles, or aircraft may cause serious signal degradation as a result of multipath or shadowing. Care must be taken that roads and taxiways do not pass through these critical areas unless it has been determined that the ground traffic will not penetrate the lower boundary of the critical area or that traffic can be restricted during instrument approach operations. Information on AZ and EL critical areas is given in chapter 5.

403. SIGNAL ACCURACY. The signal accuracy is specified at the ARD, a point in space above the runway threshold. MLS signal accuracies are specified in FAA-STD-022, Microwave Landing System (MLS), Interoperability and Performance Requirements. Signal or guidance errors are usually due to propagation effects or are generated by the transmitting equipment. These errors are identified by the effects they cause upon the aircraft and are broken down into the following components:

a. Path Following Error (PFE). That portion of the guidance signal error contributing to aircraft displacement from the desired course or glidepath. These perturbations are of low enough frequency to fall within the loop guidance bandwidth of the aircraft. For most aircraft the guidance loop bandwidth is less than 0.5 rad/sec for AZ and 1.5 rad/sec for EL. The PFE is comprised of two components which are as follows:

(1) Mean Course/Glidepath Error (MCE/MGE). The mean course error in the case of AZ, or the mean glidepath error in the case of EL, is the steady state mean bias or alignment error component of PFE. This error is considered static and is generally due to equipment beam pointing errors or very long period multipath errors.

(2) Path Following Noise (PFN). The path following noise component of PFE is that error which causes the aircraft to depart from the mean course line or mean glidepath line as appropriate. The source of this error is usually from multipath sources. It is considered dynamic in nature and must be measured by flight inspection. An additional source of PFN is from errors generated in the beam-steering mechanism which generates beam-pointing errors that fluctuate as a function of the beam-pointing angle. These beam-pointing perturbations generate a PFN component as the approaching aircraft deviates about a constant AZ course or EL glidepath angle.

b. Control Motion Noise (CMN). The portion of the guidance signal error which could affect aircraft attitude and cause control surface, wheel and column motions during coupled flight, but which does not cause aircraft displacement from the desired course or glidepath. CMN is equal to those components which lie in the frequency range of between 0.3 and 10 rad/sec for AZ and between 0.5 and 10 rad/sec for EL. The CMN component generated by multipath is considered dynamic and must be measured by flight inspection. CMN generated by the transmitting equipment can usually be measured on the ground by the portable MLS receiver.

404. MULTIPATH. A very important goal in proper MLS siting is the elimination of signal disturbances due to surrounding objects. Nearby aircraft, buildings, or terrain may cause reflection (multipath) of the scanning beam signals into the approach path, or cause

diffraction or complete blockage (shadowing) of the intended direct signal. These potential problems will be different at each MLS installation.

a. Classification. In general, multipath phenomena can be classified as either in-beam or out-of-beam. Figure 4-1 illustrates the plan view of an aircraft on final approach and a building at a small angle with respect to the approach path. This difference in coding angle between the approach path and the reflecting object is called the separation angle (Θ_{SA}).

(1) Reflections are considered in-beam when the separation angle is less than 1.7 beamwidths. Beamwidth refers to the width of the scanning beam main lobe. Multipath problems can also occur if the airport surface is tilted to a significant degree and the separation angle is less than 1.7 beamwidths. In-beam multipath can cause guidance errors and should be eliminated where practical. Appropriate in-beam multipath control techniques are discussed in chapter 6.

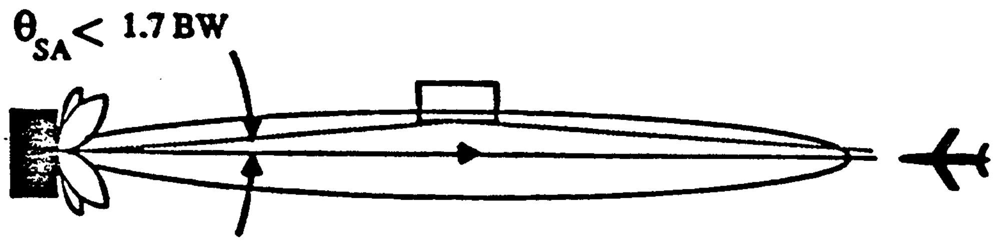
(2) Out-of-beam multipath is illustrated in figure 4-1. The multipath will be received at a different time than the direct signal and generally will not cause guidance error.

b. Nonscan Direction Multipath. Figure 4-2 gives the elevation view of the scenario of figure 4-1. Some in-beam multipath will always be present due to the airport surface. Even if the airport surface is perfectly horizontal (thus zero separation angle), the in-beam multipath can cause amplitude fluctuations which could cause problems in achieving low angle coverage. To minimize this nonscan direction multipath, the AZ antenna pattern is designed to have a very sharp cutoff near the horizon.

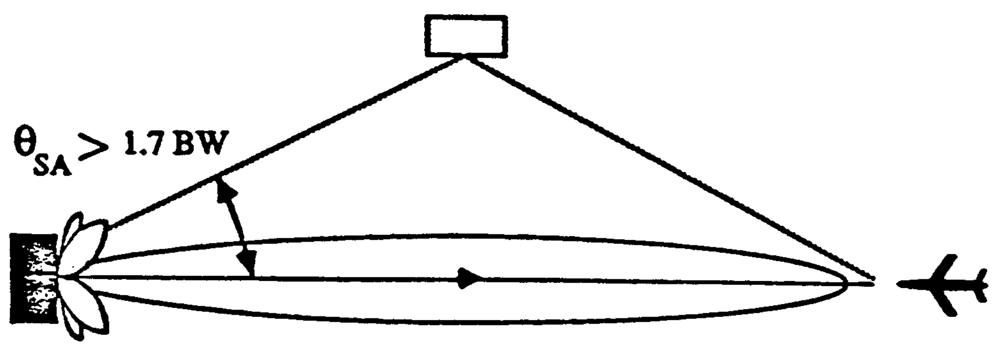
c. Elevation Multipath. These multipath principles also apply for EL guidance. Figure 4-3(a) illustrates the EL scanning beam in the presence of a flat airport surface. Rising terrain in the approach region, as shown in figure 4-3(b), can reduce the separation angle to less than 1.7 beamwidths (in-beam multipath) and cause EL guidance error.

d. In-beam EL Multipath. Multipath can also occur in the nonscan direction as shown in figure 4-4. This phenomenon, however, does not cause errors of sufficient magnitude to be of concern in typical situations. This does not mean, however, that the EL antenna may be sited close to the side of a building; significant signal amplitude fluctuations can occur if the antenna is too near the building.

FIGURE 4-1. AZIMUTH MULTIPATH CONFIGURATIONS



In-Beam



Out-of-Beam

FIGURE 4-2. AZIMUTH MULTIPATH IN THE NONSCAN DIRECTION

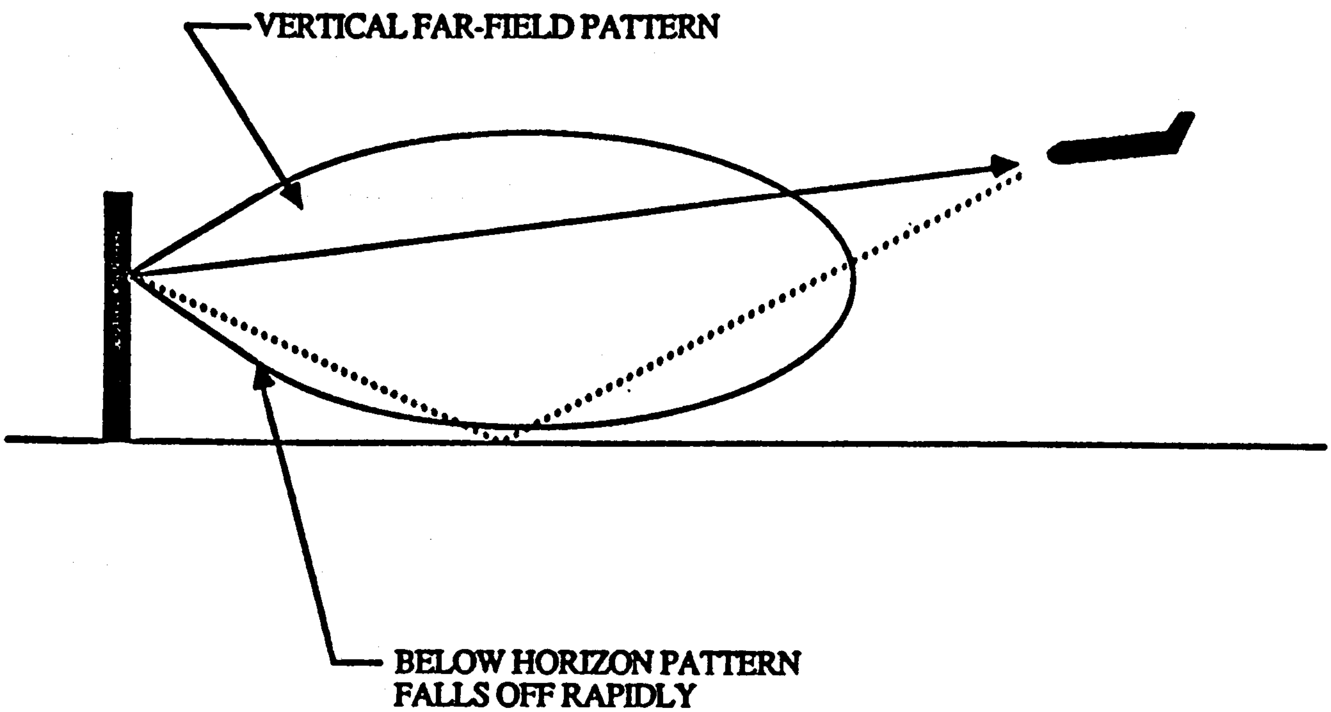
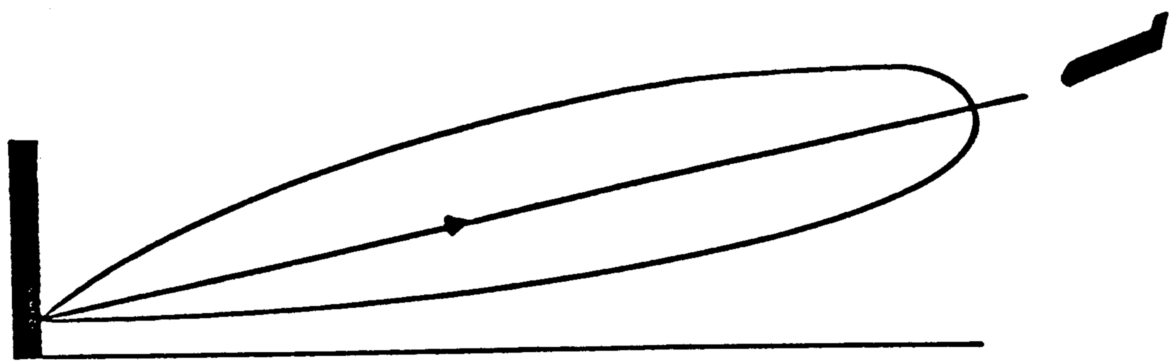
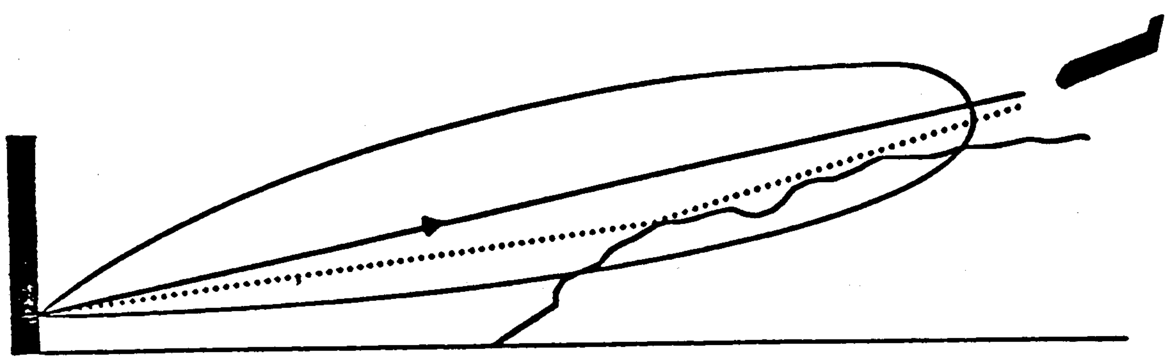


FIGURE 4-3. ELEVATION MULTIPATH IN THE SCAN DIRECTION



a) No multipath



b) In-beam multipath caused by terrain

FIGURE 4-4. ELEVATION MULTIPATH IN THE NONSCAN DIRECTION

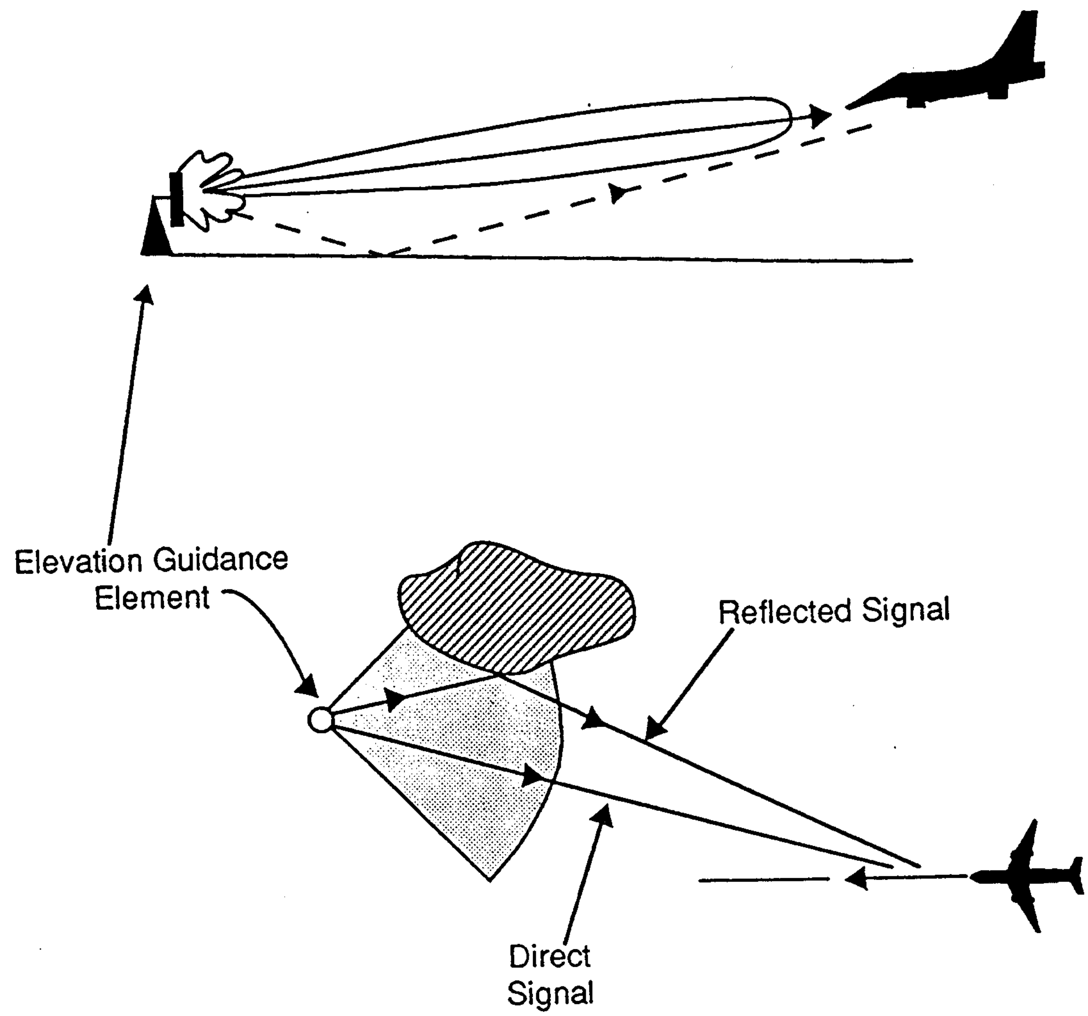
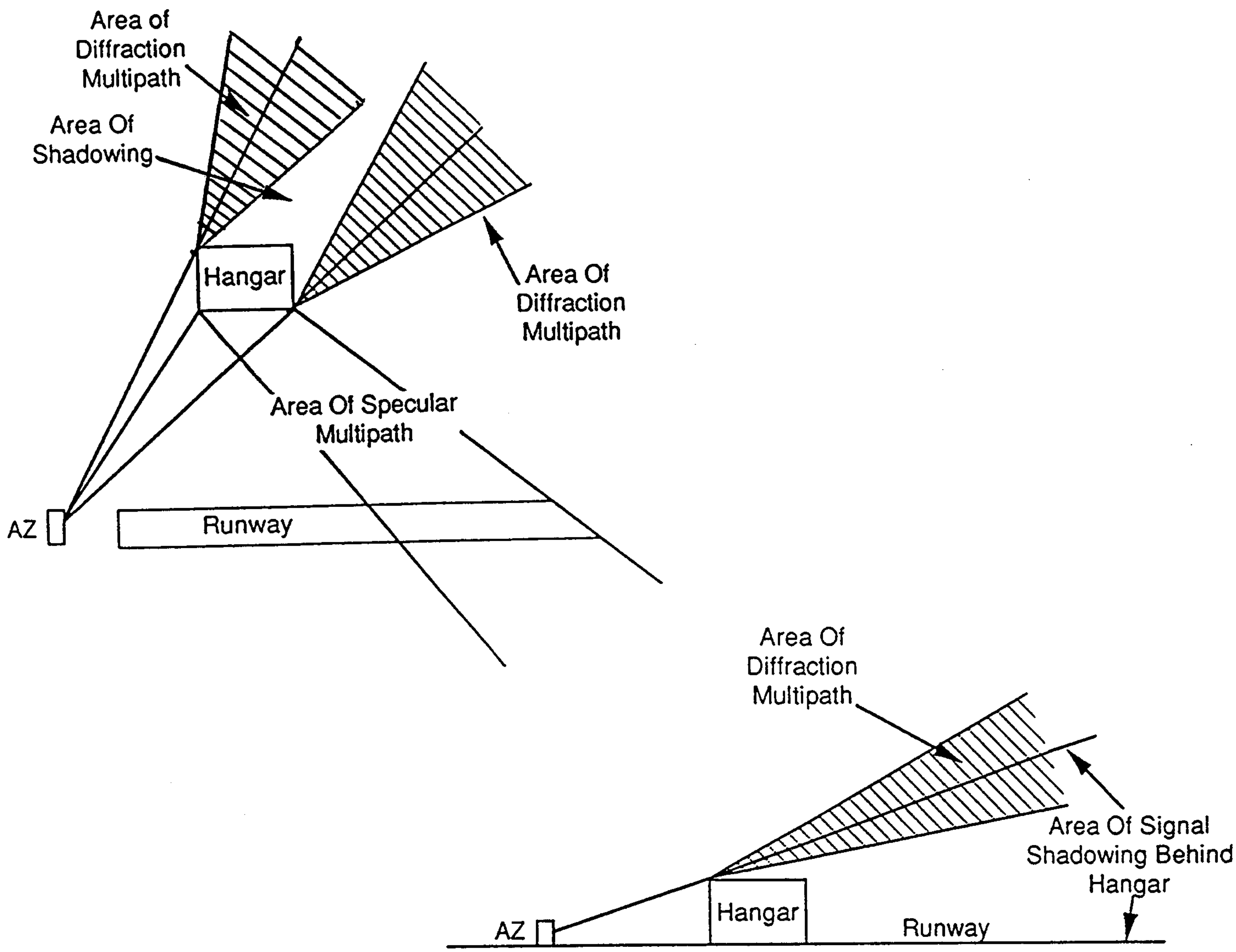


FIGURE 4-5. SHADOWING AND DIFFRACTION REGIONS



405. SHADOWING. Signal shadowing may occur due to hills, towers, humped runways, or other obstacles in the guidance volume. If the shadowing object totally obscures the line-of-sight between the airborne receiver antenna and ground antenna (see figure 4-5), only the diffracted signal, which is attenuated reaches the aircraft. If the line-of-sight is not blocked, diffracted multipath exists which can be treated as being similar to reflection multipath. The potential guidance errors due to shadowing of the direct signal depend on the signal's attenuation, possible multipath from other obstacles, and the geometry of the situation. In general, proper siting can avoid shadowing phenomena so that MLS operation is not affected.

406. OUT OF COVERAGE INDICATION REQUIREMENT. One of the requirements of the MLS design is to eliminate the presence of false courses in all regions. The design of the MLS antenna minimizes the generation of unwanted signals outside the coverage region. However, in some siting conditions, MLS signals may be reflected into regions outside of the specific coverage volume with significant strength as to cause a false course to be acquired and tracked by aircraft. These false courses can be eliminated by the use of OCI signals. The OCI signal can be radiated from up to six OCI antennas which cover the area outside of the proportional coverage sector. The requirement for OCI antennas and their alignment is established by flight inspection. The receiver, when decoding a particular angle function will look for the presence of the OCI pulses in the sector signal OCI time block. If detected, the receiver will flag, preventing the erroneous guidance. Part of the siting process is to identify objects which may reflect the scanning beam or clearance signals and cause a false course. Figure 4-6 is a typical coverage pattern with OCI for the azimuth station. Figure 4-7 shows a typical scenario for AZ where OCI might be required. A scenario whereby the EL signal can get reflected into a region above the service volume is highly unlikely. Therefore it is expected that the use of OCI for a site induced EL false course will be rare.

407.-499. RESERVED.

FIGURE 4-6. TYPICAL ANTENNA COVERAGE PATTERN WITH OCI

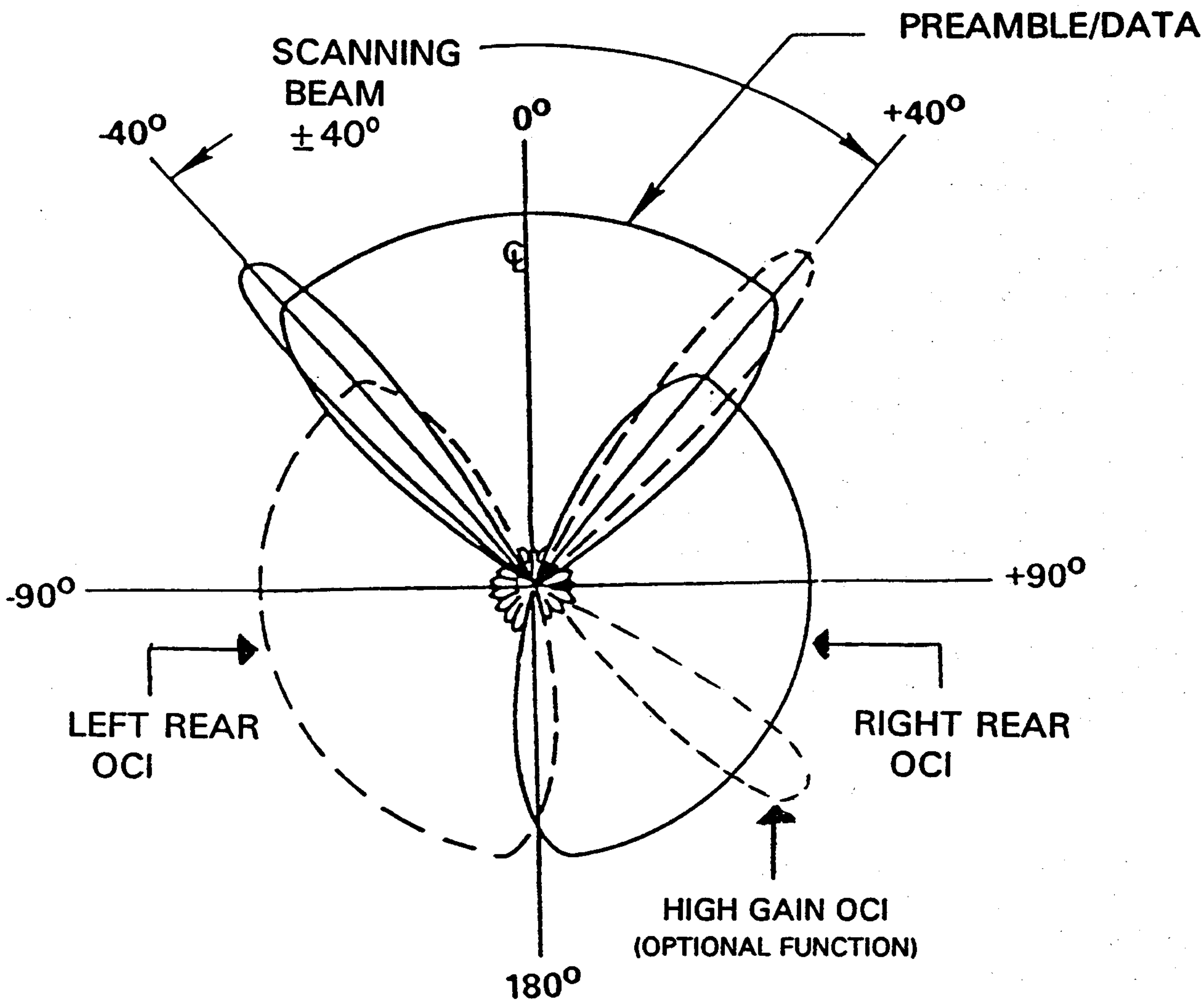
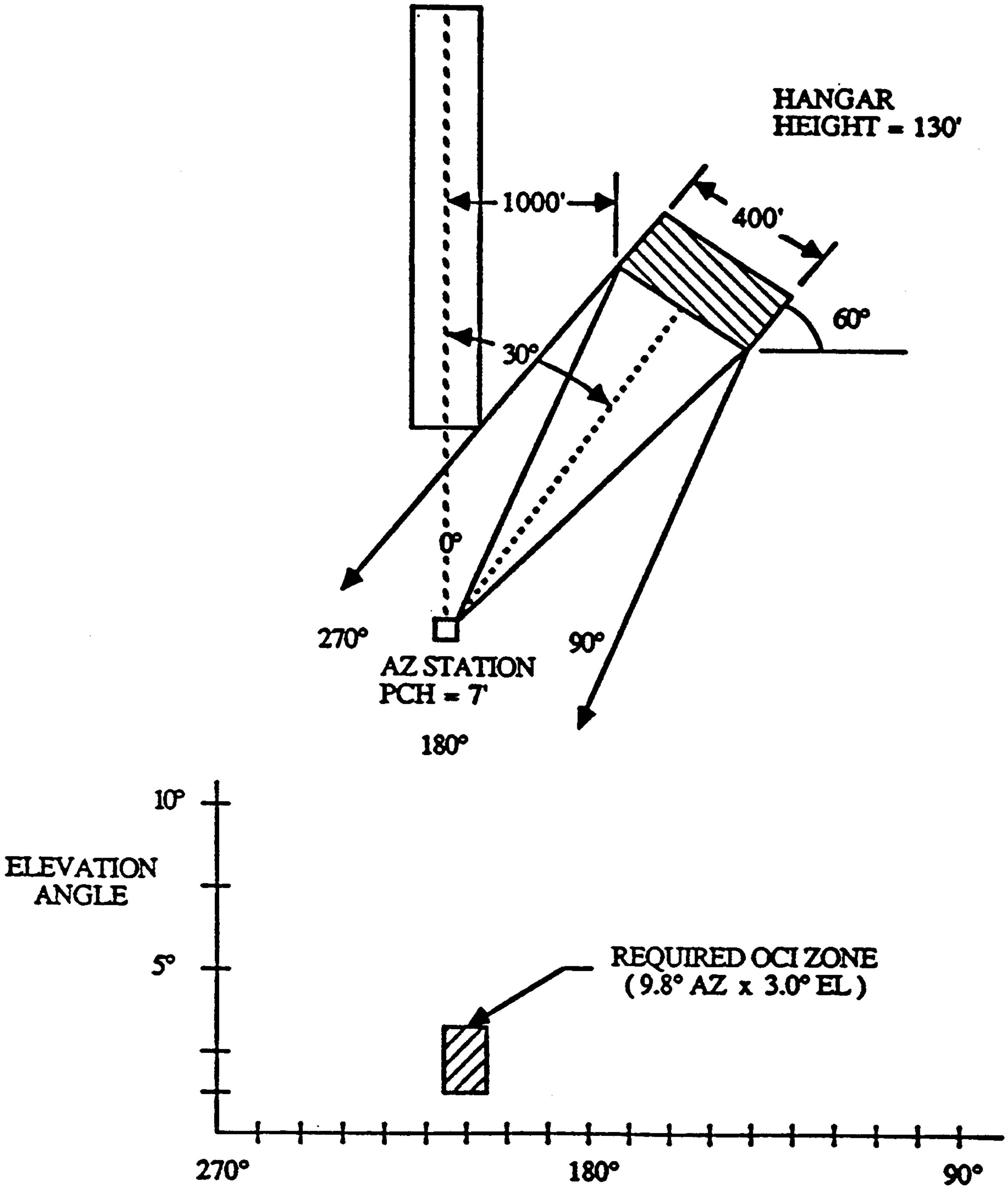


FIGURE 4-7. TYPICAL SCENARIO REQUIRING OCI



CHAPTER 5. SITING UNDER IDEAL CONDITIONS

SECTION 1. OVERVIEW

500. SITING PROCEDURES. This chapter describes the procedures for locating the AZ and EL antennas for the simplest siting situation: a flat airport surface with no hills, buildings, or other obstacles within the guidance volume, and no ILS or approach light system present. Although this is not a typical situation, more complex siting problems generally involve an alteration of the criteria presented in this chapter. In chapter 6, these situations will be discussed in detail.

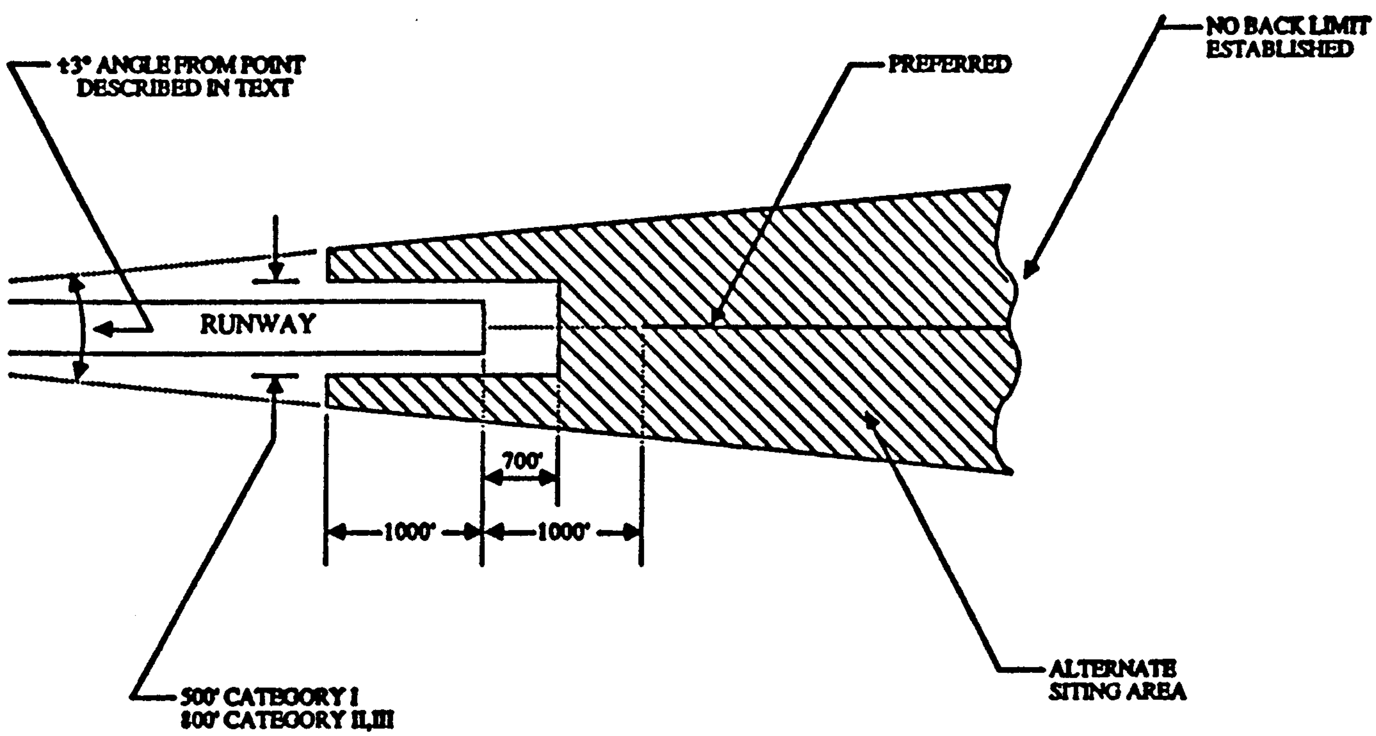
501. OBSTRUCTION CLEARANCE SURFACES. An MLS sited in accordance with this standard is fixed by its functional purpose and meets the requirements of Part 77 of the Federal Aviation Regulations (FAR). Any exceptions to the standard or special situations shall require an FAA obstruction evaluation/airport airspace analysis (OE/AAA) aeronautical study in accordance with Part 77 of the FAR to determine if a substantial adverse effect would be created for aircraft operations. In addition, the requirements of the runway safety area and the obstacle free zone criteria of Advisory Circular (AC) 150/5300-13, Airport Design, applies.

SECTION 2. AZIMUTH SITE

502. STATION LOCATION. The desired location for the AZ station is on the extended runway centerline 1,000 feet or further beyond the stop end of the runway (see figure 5-1). The distance from the stop end is influenced by the standard obstruction criteria, the necessity to protect the antenna from jet blast and oily deposits from the exhaust, and the presence of existing (or future) light lane structures.

a. Siting Considerations. The AZ antenna should be sited as close as possible to this 1,000 foot limit after consideration of future or currently existing light lanes (MLS collocation with approach lighting systems is discussed in chapter 6). The AZ antenna is frangible and could be located inside the safety area if necessary (see paragraph 502c concerning obstacle clearance). However, all efforts shall be made to site the antenna at a distance 1,000 feet or greater from stop end, employing a tower if necessary to ensure coverage in the runway region.

FIGURE 5-1. PREFERRED AND ALTERNATE LOCATIONS FOR APPROACH AZIMUTH STATION



b. <u>Centerline Siting</u>. It is recommended that the AZ antenna be sited on the extended runway centerline. If centerline siting cannot be accomplished due to a hump in the runway which shadows the threshold area (see chapter 6), lack of space, collocation with approach lights, or unsuitable terrain beyond the end of the runway, the AZ station should be located within the alternate siting area shown in figure 5-1.

(1) The MLS AZ antenna should not be offset sited if that runway end is served by a conventionally sited ILS localizer.

(2) Order 8260.36, Civil Utilization of Microwave Landing System (MLS), describes a permitted offset approach procedure in which the zero degree guidance plane intersects the extended runway centerline at a point 1100-1200 feet inside the decision height point. The offset course angular deviation must not exceed 3 degrees.

(3) Possible locations for the MLS AZ station providing an offset approach need to conform to the appropriate obstacle limitation surfaces, either the final approach surface or the transitional surfaces. Criteria to define the critical areas needed to protect MLS signal quality along procedure segments away from the centerline region are under development by the All Weather Operations Panel of the ICAO.

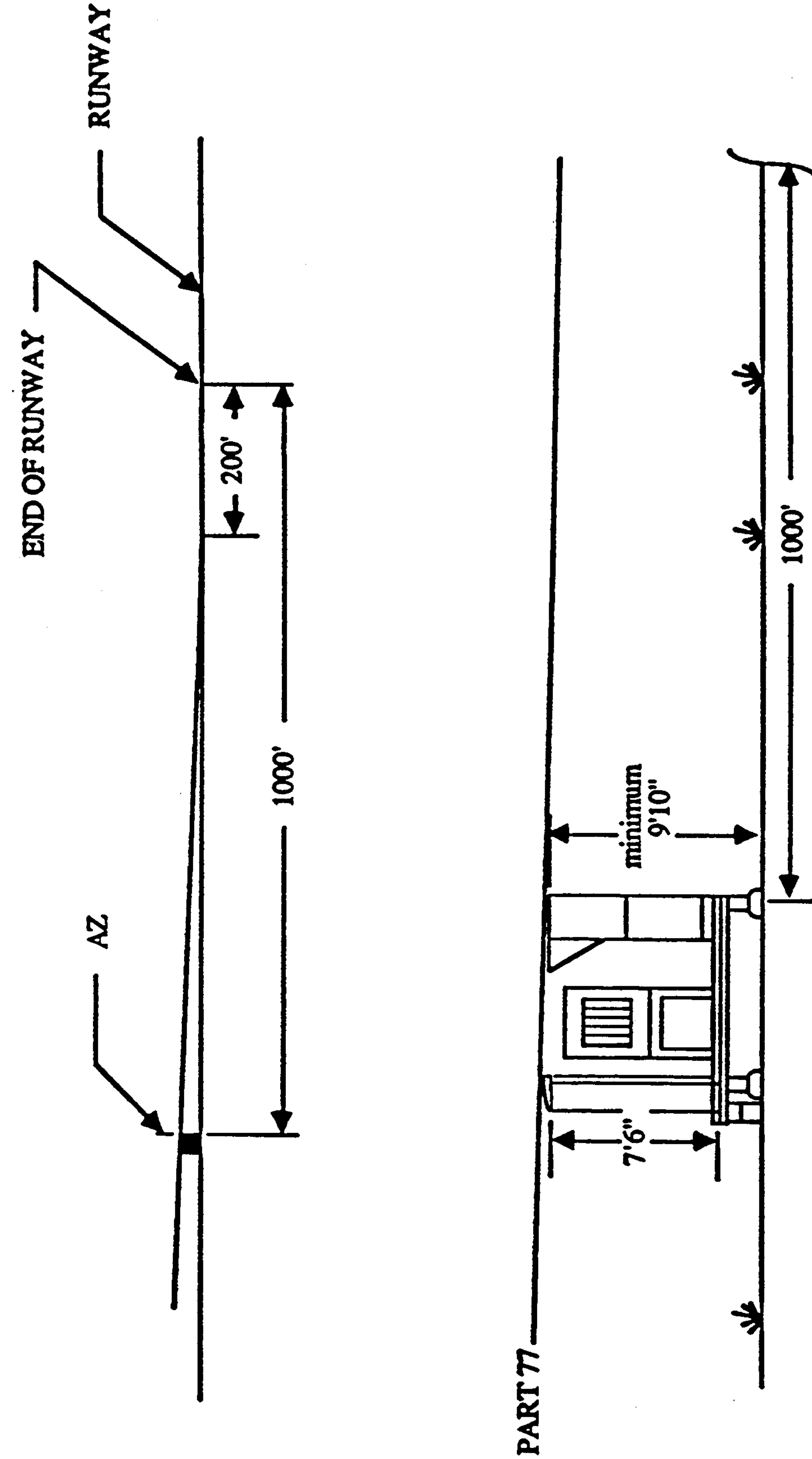
(4) The requirements to site within the preferred and alternate location area shown in figure 5-1 also pertains to facilities providing an offset approach.

c. <u>Obstacle Clearance</u>. Proper MLS siting is influenced by the necessity to meet obstacle clearance requirements. In addition to those requirements in the ground plane containing the runway, there are imaginary surfaces that rise at differing slopes from different points on the airport that shall not be penetrated.

(1) For the case of AZ siting in the approach light lane, the relevant surface for Categories II and III is the 50:1 approach surface or 34:1 for Category I. Its inner edge is 1,000 feet wide and lies perpendicular to runway centerline 200 feet off the end of the runway. The surface then extends for a horizontal distance of 10,000 feet at a slope of 50:1 and then 40,000 feet at a slope of 40:1 expanding uniformly to a width of 16,000 feet. (See figure 5-2).

(2) For AZ siting situations not covered in subparagraph 55c(1), the obstacle clearance surface criteria of Order 8260.3, United States Standard For Terminal Instrument Procedures, or Order 8260.36 applies.

FIGURE 5-2. AZIMUTH STATION INTERSECTION WITH PART 77 SURFACES

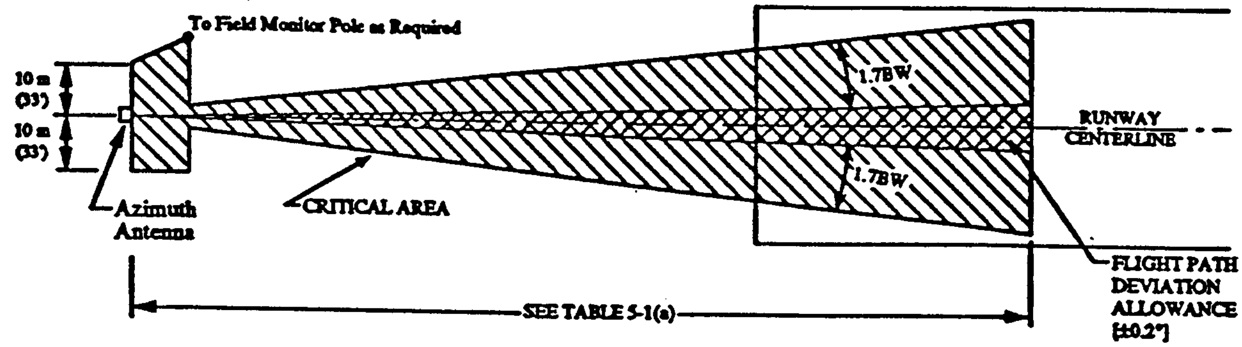


503. CRITICAL AREA. The critical area for the MLS AZ station, shown in figure 5-3, is intended to maintain the full (Category III) accuracy of the MLS guidance along centerline approach procedures. This area around the AZ antenna must be protected from the unrestricted movement of surface traffic to ensure continuous integrity of the radiated signal. Surface traffic includes taxiing aircraft and authorized vehicles.

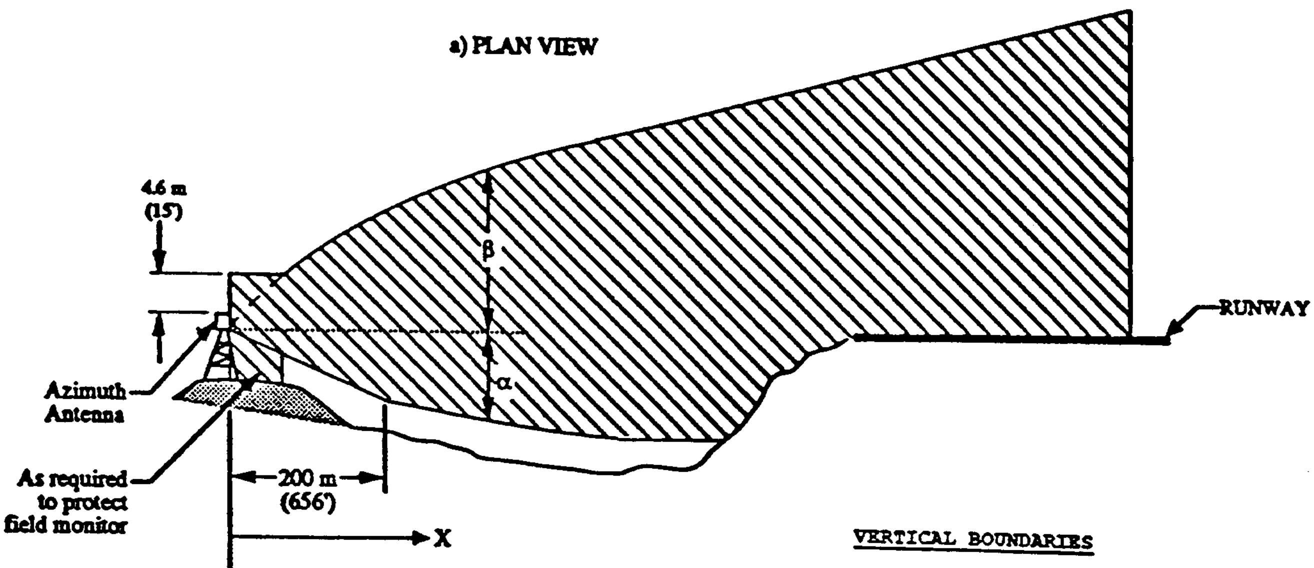
a. Critical Areas for Centerline Approach Procedures. The general formula for critical angles ($\pm$), on each side of the approach course, to be protected is (BW x 1.7) + 0.2 degrees. As shown in figure 5-3, for an AZ antenna which has a 2-degree beamwidth, the width of the critical area would be 3.6 degrees each side of antenna boresight plus the small region indicated to protect the field monitor. The 0.2-degree flight path deviation allowance is to account for the wander of the aircraft around centerline in the final approach region. The critical area lengths found in table 5-1(a) are used where the AZ antenna is normally sited on the runway centerline extended. These lengths provide signal protection for the approaching aircraft down to a height of 600 feet by which point the landed aircraft should be clear of the runway. This table accommodates interference by B-747 or B-727 aircraft in "clean" or "stressful" propagation environments using AZ antennas with beamwidths of 1 or 2 degrees. The clean and stressful sites represent extreme environments, where the first has no other interference sources (except the ground reflection) while the second assumes several reflection and diffraction sources which use up most of the accuracy margin. In the vertical, the lower boundary typically will intercept the ground near the antenna, although, for a tower mounted antenna or with depressed terrain in front, traffic can pass under the lower boundary without causing signal degradations. The upper boundary protects against helicopter or other airborne traffic moving near the antenna at slow speeds. If the azimuth antenna is offset from centerline and the critical area overlays off-runway regions where moving aircraft or vehicles may exist, the critical area lengths given in table 5-1(b) will provide signal protection for approaching aircraft down to the 250-foot decision height. The criteria are primarily based on the tailfin height. For aircraft with tailfin heights between B-727 and B-747, the latter criteria should be used.

b. Critical Areas for Advanced Procedures with Off-Centerline Segments. Criteria to define the critical areas needed to protect MLS signal quality along procedure segments away from the centerline region (e.g., on Radio Navigation (RNAV) routes) are under development by the All Weather Operations Panel of the ICAO.

FIGURE 5-3. AZIMUTH ANTENNA CRITICAL AREA



a) PLAN VIEW



b) PROFILE VIEW

VERTICAL BOUNDARIES

X m(Ft)	α m(Ft)	β m(Ft)
30 (100)	1.1 (3.4)	5.6 (18.3)
75 (250)	2.6 (8.6)	10.3 (33.8)
150 (500)	5.3 (17.2)	16.9 (55.3)
225 (750)	7.3 (24.1)	22.8 (74.9)
300 (1000)	8.5 (27.8)	28.4 (93.3)

Where: (units in meters)

$\alpha = 0.035\,X \qquad X < 200$ m

$\alpha = 2\sqrt{\lambda X} \qquad X > 200$ m

$\beta = 0.052\,X + 3\sqrt{\lambda X}$

$\lambda = 0.06$ m (0.2 Ft)

NOTES:

1. α AND β ARE MEASURED VERTICALLY FROM BOTTOM OF AZIMUTH ANTENNA APERTURE
2. BW - BEAMWIDTH

TABLE 5-1. AZ CRITICAL AREA LENGTHS

TABLE 5-1(A). AZ CRITICAL AREA LENGTHS FOR CENTERLINE APPROACHES (AZ ANTENNA SITED ON CENTERLINE)[1]

AZ to threshold distance	2 Degree Beamwidth					1 Degree Beamwidth		
	1830 (6000)	2135 (7000)	2440 (8000)	2745 (9000)	3050 (10000)	3350 (11000)	3660 (12000)	3960 (13000)
B-747 clean site	490 (1600)	520 (1700)	580 (1900)	610 (2000)	640 (2100)	670 (2200)	700 (2300)	700 (2300)
B-727 clean site	300 (1000)	300 (1000)	300 (1000)	300 (1000)	300 (1000)	300 (1000)	460 (1500)	490 (1600)
B-747 stressful site	490 (1600)	550 (1800)	580 (1900)	640 (2100)	700 (2300)	730 (2400)	760 (2500)	820 (2700)
B-727 stressful site	300 (1000)	300 (1000)	300 (1000)	460 (1500	550 (1800)	460 (1500)	490 (1600)	550 (1800)

1/ Distances are in meters (feet). Values in both units have been rounded.

NOTE: For locations where one degree beamwidths are used instead of the 2 degree, these values still apply although they will be conservative.

TABLE 5-1(B). AZ CRITICAL AREA LENGTHS FOR CENTERLINE APPROACHES (OFFSET AZ INSTALLATION)[2]

AZ to threshold distance	2 Degree Beamwidth					1 Degree Beamwidth		
	1830 (6000)	2140 (7000)	2440 (8000)	2750 (9000)	3050 (10000)	3360 (11000)	3660 (12000)	3960 (13000)
B-747 clean site	640 (2100)	730 (2400)	790 (2600)	880 (2900)	880 (2900)	920 (3000)	940 (3100)	1000 (3300)
B-727 clean site	300 (1000)	300 (1000)	300 (1000)	300 (1000)	300 (1000)	300 (1000)	490 (1600)	550 (1800)
B-747 stressful site	670 (2200)	760 (2500)	820 (2700)	880 (2900)	1010 (3300)	980 (3200)	1070 (3500)	1130 (3700)
B-727 stressful site	300 (1000)	300 (1000)	330 (1100)	460 (1500)	550 (1800)	490 (1600)	520 (1700)	550 (1800)

2/ Distances are in meters (feet). Values in both units have been rounded.

NOTE: For locations where one degree beamwidths are used instead of the 2 degree, these values still apply although they will be conservative.

c. Requirements. Parking of surface vehicles in the critical area is prohibited and all traffic shall remain clear of the area except as provided in the latest edition of Order 7110.65, Air Traffic Control. Vegetation shall not be permitted to grow to such a height that it extends up into the critical area.

d. Aircraft Specific Hold Lines. The siting engineer shall coordinate with Air Traffic and Airports on the desirability for aircraft specific hold lines. In many cases wide body aircraft (B747, L1011) may be the only aircraft which cause signal degradation of the MLS signal where the taxiway violates the AZ critical area. Actual onsite testing with flight inspection may be required to implement this feature.

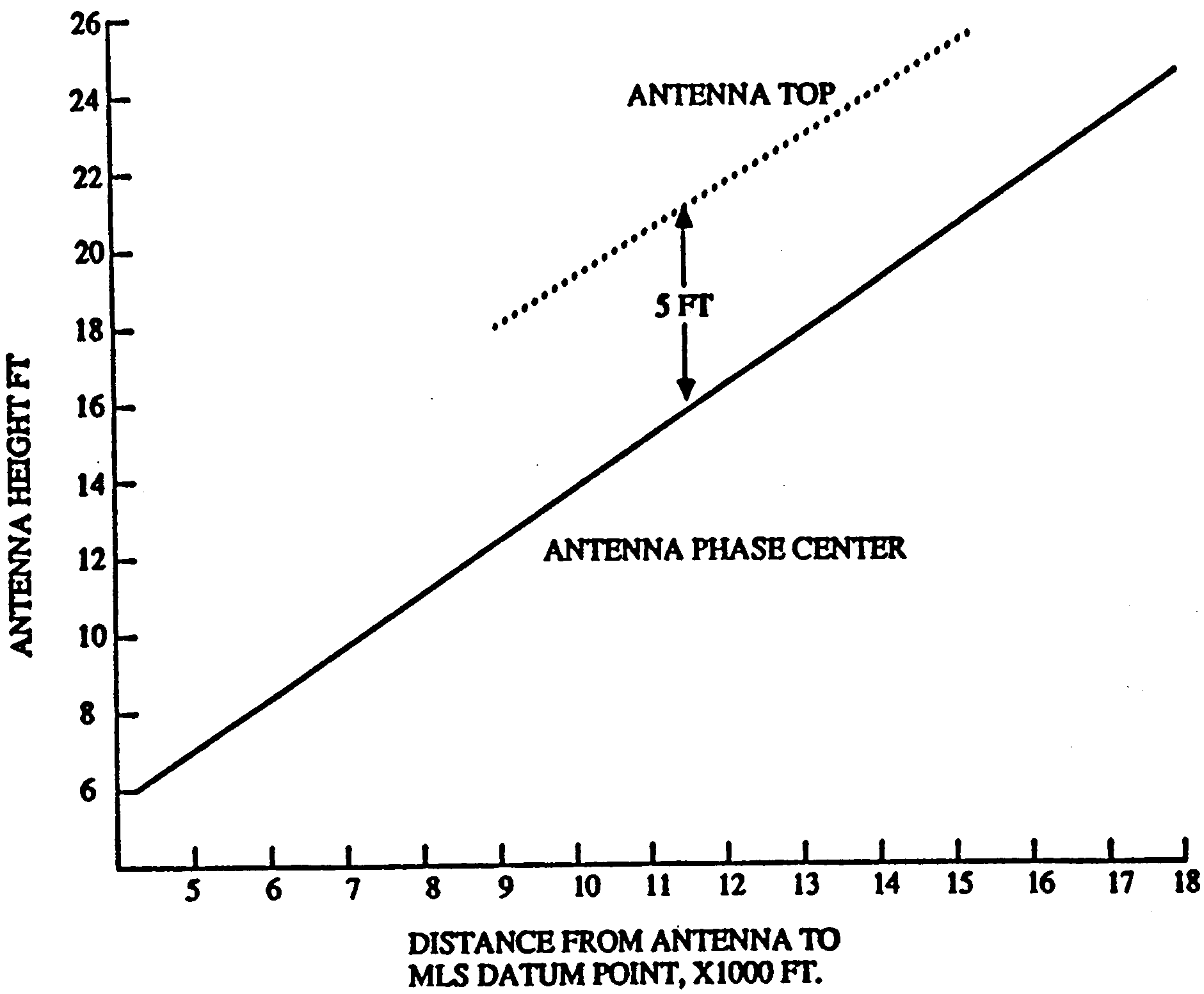
e. Collocation. If the AZ antenna is located with a localizer, both the ILS and MLS critical areas must be protected from ground traffic.

SECTION 3. DME/P SITE

504. LOCATION. The preferred location for the DME/P is at the AZ site. However, this may cause the DME/P antenna to violate obstacle clearance surfaces (Part 77) when AZ-DME/P site is about 1,400 feet or less from the stop end of the runway and located in the light lane. The distance from the stop end is found by determining the necessary antenna height to ensure adequate DME/P signal at 8 feet above the runway surface from figure 5-4, and checking to see if the 50:1 surface is violated for that particular DME/P antenna site. If so, the DME/P antenna may be moved further back (and its height readjusted) until it does not penetrate the 50:1 surface. It should be noted that in figure 5-4 a difference of 5 feet between the phase center and the top of the antenna was assumed. The siting engineer should always check the manufacturer's specifications for the particular antenna being installed before making siting decisions. In choosing a site for the DME antenna, the possibility of carrier wave (CW) interference must be considered. This interference is caused by emissions from the DME interrogators of aircraft in close proximity to the DME antenna. In order to minimize these effects, the DME antenna should be located at least 600 feet from any aircraft movement area, i.e., taxiways, ramps. Where such siting is not possible, local restrictions on DME interrogator operations may be required.

505. ANTENNA OFFSETTING. If the DME/P antenna penetrates the approach light plane or the 50:1 surface, the antenna may be offset laterally from the AZ station. An offset greater than 200 feet is required to preclude penetration of the obstacle free zone surfaces.

FIGURE 5-4. TYPICAL RELATIONSHIP BETWEEN DME/P ANTENNA PHASE CENTER HEIGHT AND DISTANCE TO TOUCHDOWN



a. In all cases, it is preferable to keep the offset as small as possible. The largest allowable offset is 511 meters, since this is the highest number that can be coded for in the auxiliary data word that contains the DME/P siting geometry. Offsets larger than this mean that the DME is no longer associated with the MLS.

b. As shown in figure 2-19, the DME/P is capable of providing 360 degrees coverage. If there are obstacles that will cause blockage, the antenna shall be sited such that the blockage occurs in regions that do not include the AZ (or BAZ, if one is present) coverage sector as well as DME arc sectors.

506. DME/P MULTIPATH INTERFERENCE.

a. System Design. Due to the DME/P system design, multipath interference should not be of concern at the vast majority of runways. For Categories I and II operations in particular, where guidance is required to a minimum altitude of 100 feet, multipath should not pose any problems. At altitudes lower than this there are certain building geometries that may result in multipath with amplitudes and time delays that could cause significant errors. The time delay for the multipath versus the direct signal that can cause errors is 300 nanoseconds or less. This is equivalent to a path length difference of 300 feet or less.

b. Evaluating The Multipath Environment. Path length differences for a multipath source (to an aircraft in the approach region) can be computed using simple ray tracing or by use of the MLS computer model. Smaller objects such as aircraft and ground vehicles will not cause significant errors. However, there is a potential for signal blockage, particularly for operations that require coverage near the runway surface. In those cases, care should be taken to site the antenna such that taxiing aircraft or vehicles will not cause significant blockage. Since the DME/P is normally sited at or near the AZ antenna, the critical areas established to protect AZ should also be sufficient to protect the DME/P.

SECTION 4. ELEVATION SITE

507. ANTENNA LOCATION. Optimum siting of the EL station is determined by coverage/multipath problems, installation and maintenance considerations, and conical effects. In addition, the siting of the EL station antenna is dependent upon the following factors: (1) The chosen approach reference datum height (H), (2) the minimum glidepath angle (MGP), (3) the phase center height of the EL antenna, and (4) the selected offset from runway centerline (OS).

a. Approach Reference Datum Height and Minimum Glidepath. The regional Flight Standards personnel shall determine the ARD height and the minimum glidepath angle of the MLS EL station. Order 8260.34, Glideslope Threshold Crossing Height Requirements, governs the selection of the height of the ARD. In selection of the ARD and the minimum glidepath, factors to be considered will include obstruction criteria and types of expected operations on that particular runway. In most installations, the minimum glidepath will be 3 degrees and the approach ARD will be between 50 and 60 feet.

b. Obstacle Clearance. Proper MLS siting is influenced by the necessity to meet obstacle clearance requirements. Considerations are the plane containing the runway and the imaginary surfaces that rise at differing slopes from different points on the airport that should not be penetrated.

(1) For the case of EL siting, figure 5-5 depicts the controlling surface restrictions. These surfaces are specified in FAR Part 77 which shall be consulted to determine obstacle clearance. See paragraph 502 for further guidance.

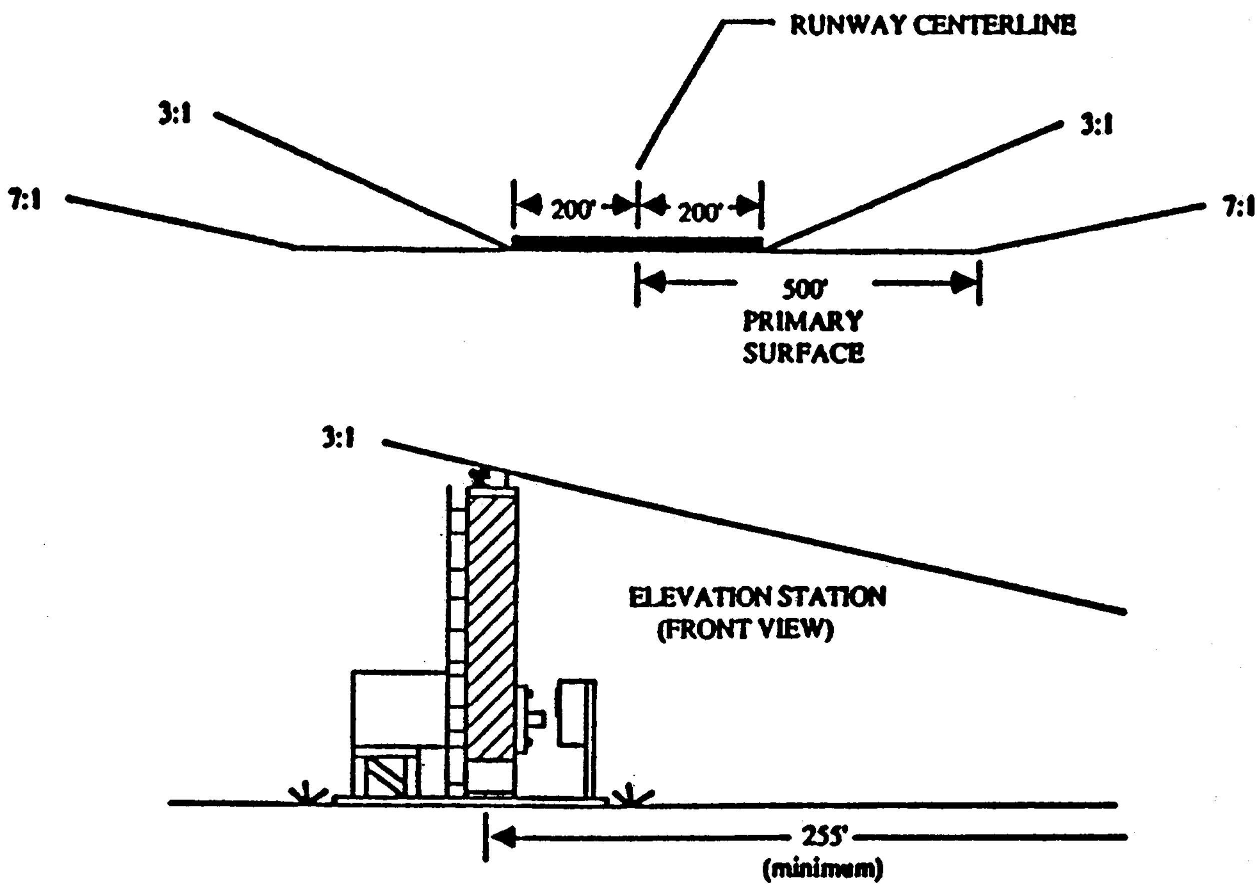
(2) For situations not covered in subparagraph 507b(1), the obstacle clearance surface criteria of Order 8260.3 or Order 8260.36 applies.

c. Determining Antenna Offset. The preferred offset (OS) of the EL antenna from runway centerline for siting of the EL station antenna is in the range of 400 to 600 feet on either side of runway centerline. However, an antenna offset in the range between 250 and 400 feet from centerline may be acceptable. Within these ranges, the choice of antenna OS is further restricted by taxiway-to-obstacle separation criteria and the runway safety areas/obstacle free zones of any adjacent or crossing runways (see AC 150/5300-13). OS considerations when collocating with an ILS glideslope are covered in chapter 6.

d. Determining Antenna Setback. Once the minimum glidepath angle and the height of the ARD are established by Flight Standards, the location of the antenna from threshold is determined in the following manner.

(1) As shown in figure 5-6, the setback distance (SB) is calculated using the approach reference datum height (H), the antenna phase center height as measured above the approach surface base plane (ASBP), and the tangent of the minimum glidepath angle. Note that the offset does not affect the calculation of the setback. The height of the phase center of the EL antenna is adjustable by the utilization of antenna towers. As the phase center of the antenna is raised, the SB from runway threshold is decreased. This feature allows the siting engineer to move the EL antenna away from or across interfering taxiways or obstructions.

FIGURE 5-5. TRANSITIONAL SURFACES



(2) The ideal EL antenna setback would cause the asymptote of the minimum glidepath to intersect the MLS ARD. This SB is illustrated in figure 5-6 and is calculated using the formula included in that figure. As the antenna offset from runway centerline increases, the hyperbolic effect also increases and at offsets approaching 600 feet the effect may begin to present an operational problem. The difference in height (HDIF) above threshold between the hyperbolic glidepath and the linear asymptote may be calculated using the appropriate formula from figure 5-6. This difference is graphically shown in figure 5-7 which plots the hyperbolic threshold crossing height (TCH) as the antenna offset is increased. The HDIF should be kept to a minimum. If this difference exceeds 10 feet, it could present an operational problem, and alternative siting should be explored.

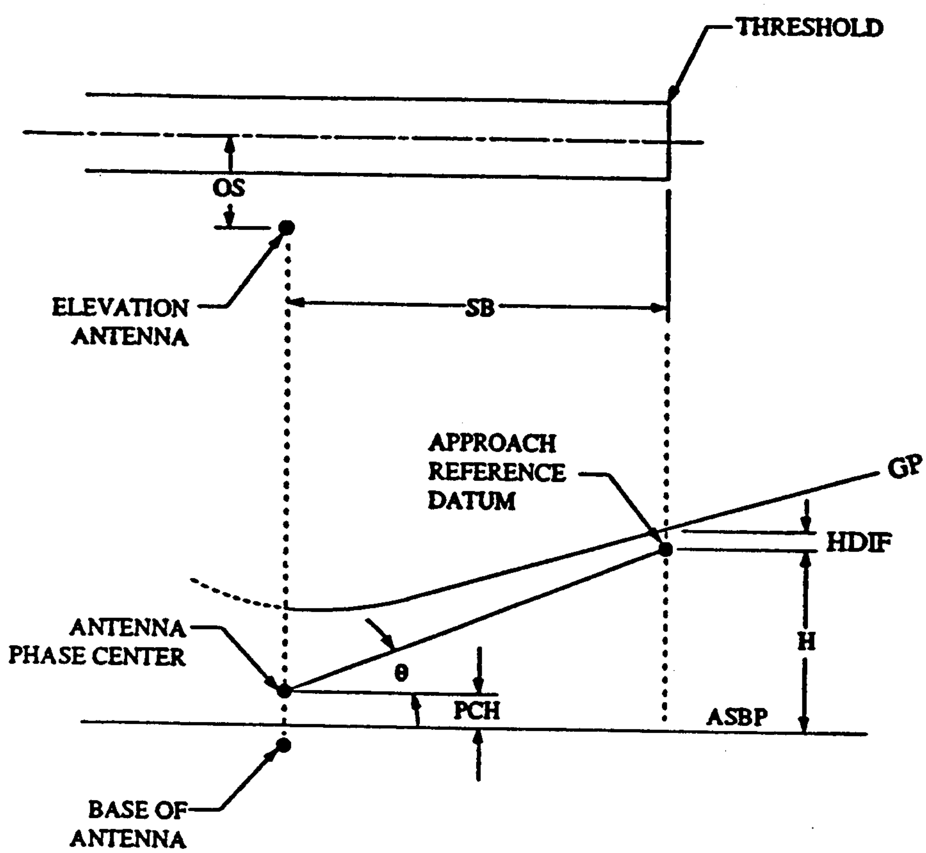
(3) Figure 5-8 gives the siting area which will maintain the asymptote at a height of 50 feet above threshold while keeping the path height to less than 60 feet above threshold (a phase center height of 7 feet and a 3 degree glidepath were assumed).

508. CRITICAL AREA. The EL station critical area is shown in figure 5-9. This area must be protected from unlimited movement of surface traffic to ensure the continuous integrity of the EL signal-in-space.

a. Critical Area for Centerline Approach Procedures. Laterally, the EL critical area extends from the runway edge to a line parallel to centerline located 33 feet beyond the antenna and as necessary to include the far field monitor (see figure 5-9 for the specific geometry). The length of the critical area appropriate for various sites, aircraft sizes, and antenna beamwidths is found in the table included on figure 5-9. It is important to note that the EL critical area may not extend down to ground level, and thus, in many cases, aircraft can pass under the critical area or, as a minimum, hold in front of the EL site as long as the tailfin is excluded. For normal siting of a 1-degree beamwidth antenna and flat ground, the fuselage of most aircraft will fit under the lower boundary of the critical area. For an antenna with a 1.5-degree beamwidth, limited penetration may be tolerated by an aircraft fuselage which is perpendicular to centerline. At sites performing well within tolerances, aircraft may hold in front of the antenna provided: (1) the separation angle between the glidepath and the top of the aircraft fuselage is at least 1.5 degrees; and, (2) the aircraft tailfin is excluded from the critical area. The criteria are primarily based on the tailfin height. For aircraft with tailfin heights between B-727 and B-747, the latter criteria should be used.

b. Critical Areas for Advanced Procedures with Off-centerline Segments. Criteria to define the critical areas needed to protect MLS signal quality along procedure segments away

FIGURE 5-6. COMPUTATION OF ELEVATION ANTENNA SET-BACK



KNOWN: OS, θ, H, PCH

FIND: SB

$$SB = \frac{H - PCH}{\tan \theta}$$

FIND: HDIF

$$HDIF = \left(\sqrt{SB^2 + OS^2}\right)\left(\tan \theta\right) + PCH - H$$

FIGURE 5-7. MLS 3-DEGREE GLIDEPATHS AND THE LINEAR ASYMPTOTE FOR VARIOUS ANTENNA OFFSETS FROM RUNWAY CENTERLINE

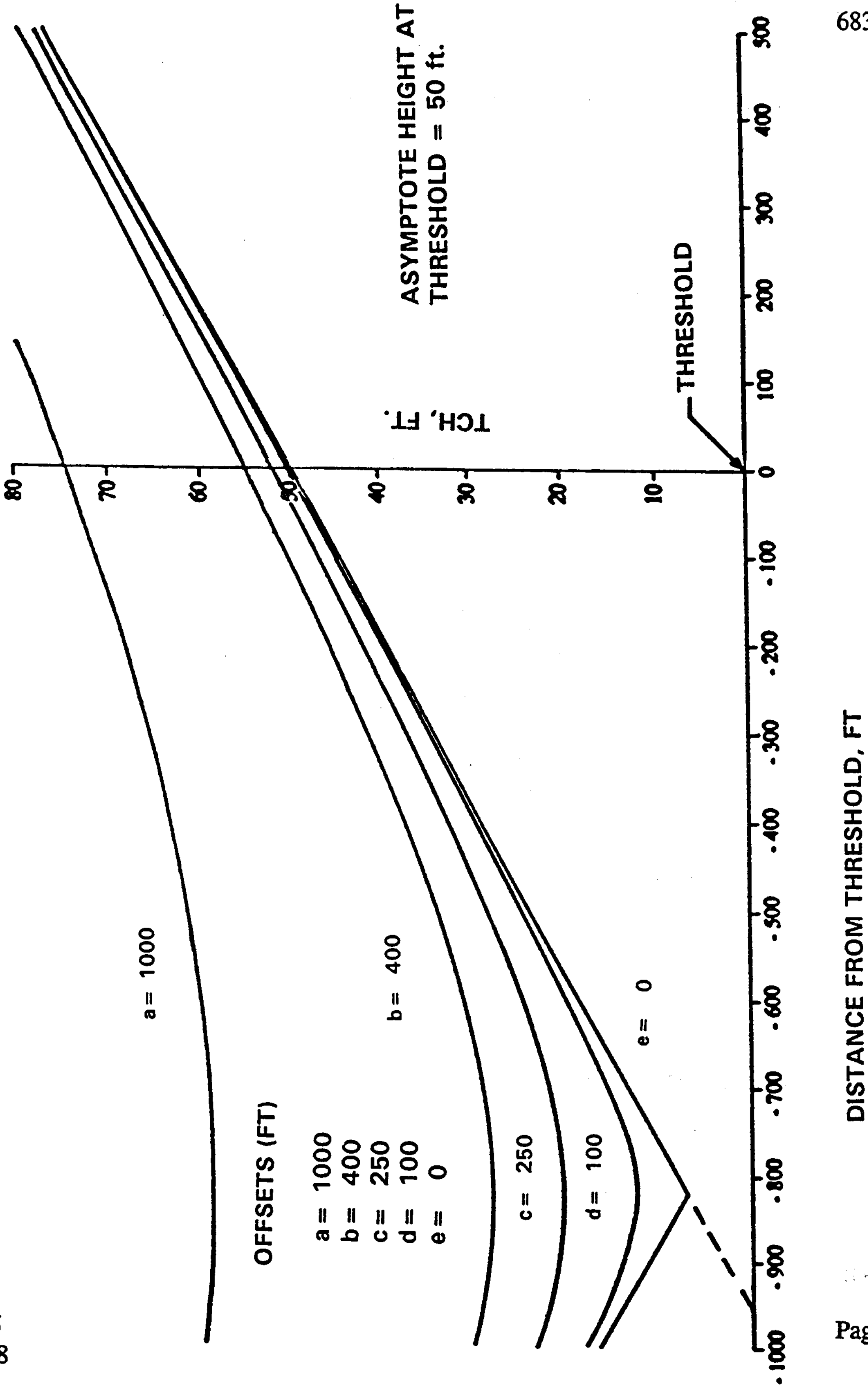


FIGURE 5-8. ELEVATION SITING AREA WHICH YIELDS A PLANAR GLIDEPATH OF AT LEAST 50 FEET WHILE KEEPING THE HYPERBOLIC PATH CROSSING HEIGHT LESS THAN 60 FEET

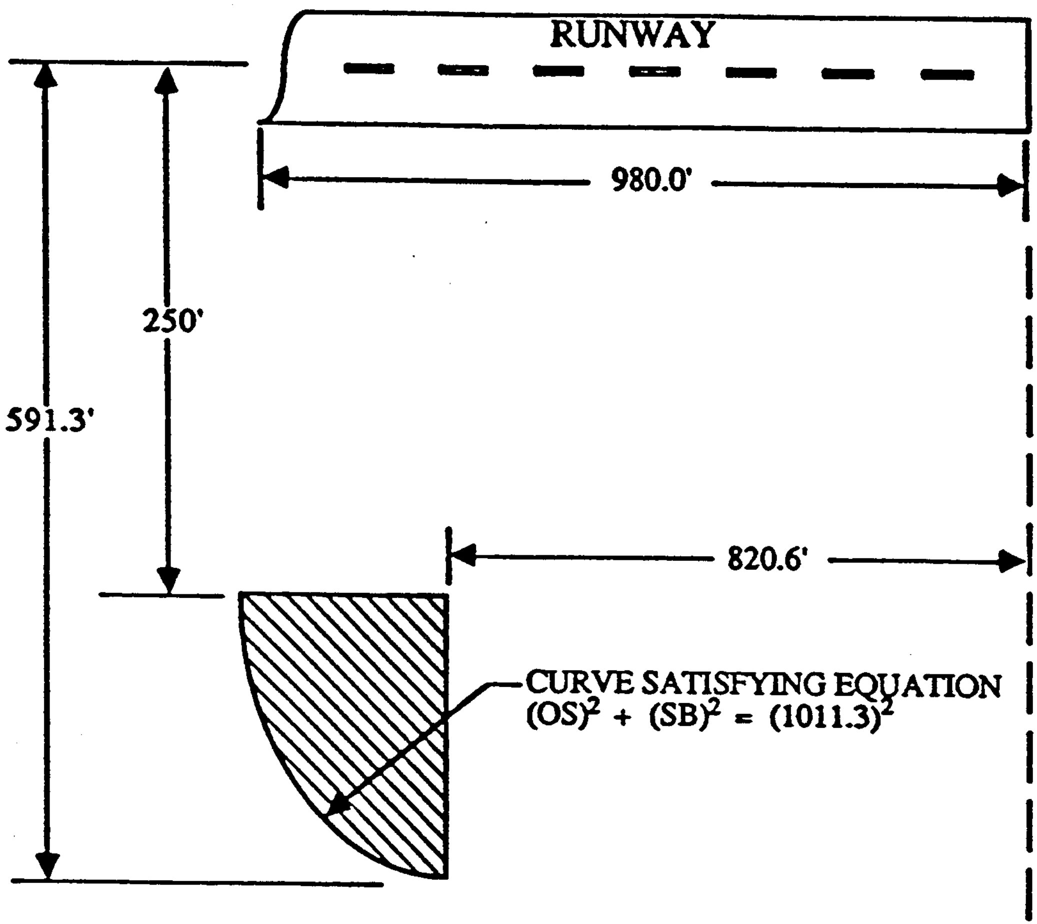
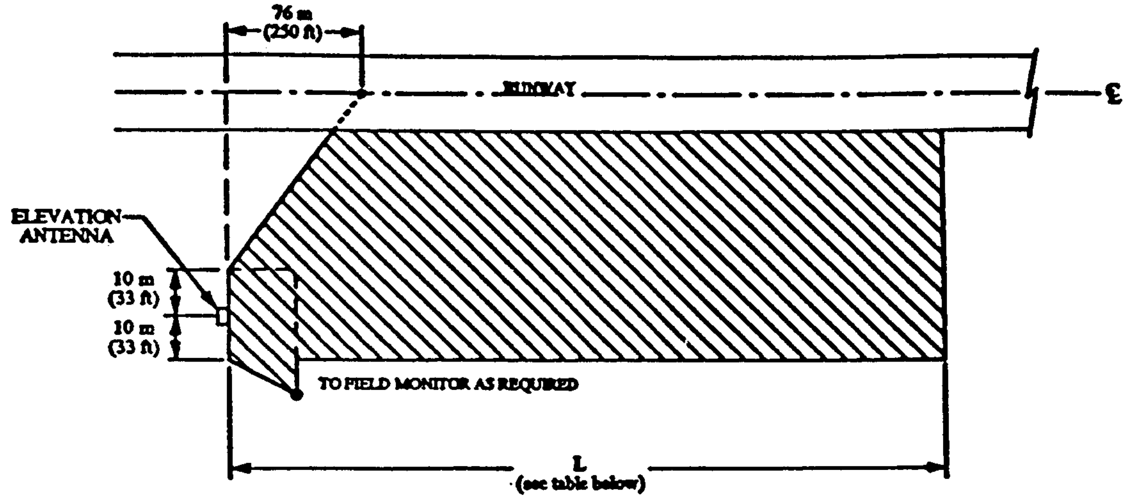
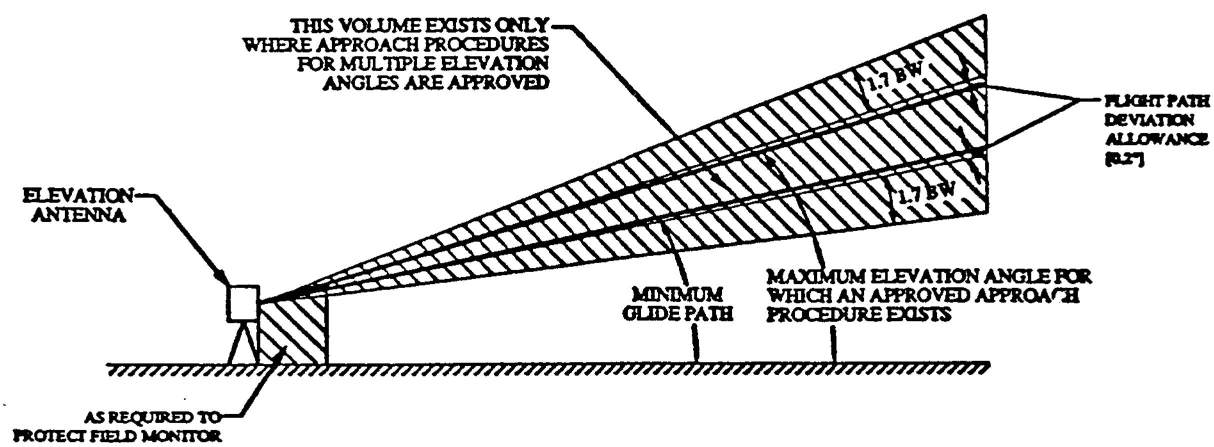


FIGURE 5-9. ELEVATION ANTENNA CRITICAL AREA



BEAMWIDTH	CLEAN SITE		STRESSFUL SITE	
	747	727	747	727
1.0°	320 m (1050 ft)	170 m (560 ft)	385 m (1260 ft)	180 m (600 ft)
1.5°	400m (1310 ft)	250 m (820 ft)	565 m (1860 ft)	300 m (990 ft)

a). PLAN VIEW



b). PROFILE VIEW

from the centerline region (e.g., on RNAV routes) are under development by the All Weather Operations Panel of the ICAO.

c. Modification Techniques. If the EL critical area is interfering with operationally desirable aircraft movements, the siting engineer can take the following actions:

(1) Raise the phase center. The antenna can be raised and moved towards the runway threshold in order to move the EL antenna to the threshold side of the offending taxiway or to assure that taxiing aircraft will not penetrate the lower boundary of the critical area (see paragraph 508a). Limitations of these techniques include violation of the 7:1 surfaces, which can be minimized by increasing the offset, and operational concerns about antenna conical effects.

(2) Multiple aircraft hold lines. The siting engineer can coordinate with air traffic and airports on the desirability for aircraft specific hold lines. In many locations, only aircraft with very tall tailfins (e.g.,B747, L1011) may be required to hold short of the EL critical area. Actual onsite testing with flight inspection may be needed to validate this technique.

d. Collocation. If the EL antenna is located with an ILS glideslope antenna, both the ILS and MLS critical areas must be protected.

SECTION 5. FIELD MONITORS

509. GENERAL. Both the AZ and EL stations include field monitors that are installed in association with the scanning beam antennas. The field monitor's primary purpose is to monitor mechanical stability of the antennas. An integral monitor (within the antenna aperture) is used to monitor the electrical stability.

a. Integral Monitor. The integral monitor sums the signals from each antenna element to reproduce the antenna pattern as it would be seen in the far field, and it is designed to monitor at only one angle which cannot be changed.

b. Field Monitor. The field monitor can be placed at any angle within the scan coverage of the antennas. However, it is required that either the integral or field monitor (or both) be within one beamwidth of the zero degree course (AZ) and the minimum glidepath (EL). This is to ensure maximum system integrity for the final approach course.

c. Azimuth. Usually, the AZ integral monitor is designed to monitor at zero degrees. The field monitor performs best when located on the 20-degree radial but it can be placed at any angle within the scan coverage. It is not desirable to place the field monitor within ± 10 degrees of the azimuth centerline because of the potential for blockage of the signal in space, thereby degrading performance. Since the final approach course is normally zero degrees, it is best to keep the region around this angle as free of distortions as possible. However, if the final approach course is other than 0 degrees or if the antenna has been skewed for coverage requirements, the field monitor should be placed at an azimuth which will not interfere with the final approach. The height of the AZ field monitor should be elevated 0.5 degrees (± 0.1) above the azimuth phase center height to ensure adequate signal strength.

d. Elevation.

(1) Similarly for EL stations, the integral monitor angle depends upon the specific equipment design and will determine at what angle the field monitor needs to be placed. If the integral monitor is already within one beamwidth of the minimum glidepath, then generally the field monitor is placed high enough to ensure adequate signal strength and prevent signal blockage from ground traffic. However, overall monitor pole height should not penetrate obstacle clearance surfaces.

(2) The EL field monitor can be placed at any azimuth angle within coverage, 40 degrees maximum. The preferred range is 15 to 25 degrees off antenna boresight away from the runway with best performance at the 20 degree azimuth angle. This eliminates its possible shadowing and degradation of the signal in space along the final approach course. The siting engineer must ensure that obstacle clearance planes are not penetrated by the EL monitor mast.

e. Siting Restrictions. The AZ field monitor mast should not be sited in the approach light lane. Siting in the light lane may cause problems with interference/shadowing of the signal detected by the field monitor. When required to site in the light lane, the field monitor must be of sufficient height to ensure adequate signal and minimum interference by the lights. In addition, the field monitor masts shall not penetrate the applicable surface requirements. Additionally, siting engineers shall apply this criteria to prevent penetration of any planned or future surface requirements for lighting.

510. DISTANCE REQUIREMENTS. The distance at which the field monitor is placed primarily depends upon the beamwidth of the antenna, although there are other design factors which can also affect the distance requirements. For a 2- or 3-degree beamwidth AZ antenna, the field monitor is nominally placed at 100 to 150 feet from the AZ antenna. For a 1 degree AZ antenna the field monitor is placed at 200 to 300 feet. For EL field monitors, the nominal distances are as follows: 2-degree beamwidth, 150 to 200 feet; 1.5-degree

beamwidth, 200 to 300 feet; 1-degree beamwidth, 250 to 350 feet. The manufacturers' instruction books should be consulted to determine maximum and minimum siting distances.

a. Long Distance Requirements. The optimum field monitor distance is a compromise among competing factors. There are three factors which would tend to require long distances.

(1) Placement of the monitor in the far field. In the near field of the scanning beam antenna, the apparent beamwidth broadens. In addition, the monitor becomes more insensitive to phase errors in the scanning antenna.

(2) Limit the number of false alarms, thereby increasing system availability. A field monitor in the near field of the antenna is more susceptible to transient effects (mechanical movement, etc.) that do not affect the signal in space but could cause a false alarm.

(3) Reduction of signal shadowing or reflection. Placement of the monitor in the far field helps to eliminate degradation of the signal in space caused by the monitor's shadowing or reflection of the transmitted signal.

b. Short Distance Requirements. There are two factors which would tend to move the monitor as close as possible to the scanning antenna.

(1) Limit the susceptibility to false alarms due to vehicle and aircraft traffic. Any multipath or blockage caused by a vehicle in between the scanning beam and monitor antennas will cause erroneous signals to be decoded by the monitor thereby causing an alarm. The likelihood of this is reduced if the distance separating the antennas is small.

(2) Limit the possible penetration of obstacle clearance planes by the monitor pole. In the case of EL station, since the field monitor is generally placed at an angle of 2 degrees or higher, the further away it is from the scanning antenna the higher it must be. For AZ the field monitor is nominally placed at the same height as the phase center of the scanning antenna. However, as the distance is increased, it becomes necessary to raise the height of the monitor antenna to assure an adequate signal level.

c. Manufacturer Recommendations. The siting engineer shall consult the equipment instruction book for recommended siting distances for the field monitors. In addition, he/she should identify the monitor angle of the integral monitoring before siting the field monitor to ensure compliance with the one beamwidth requirement of subparagraph 509b.

511.-599. RESERVED.

CHAPTER 6. SPECIFIC SITING CONCERNS

600. OVERVIEW. This chapter discusses methods of analysis and techniques to deal with multipath and shadowing problems, as well as criteria for collocation with ILS and approach light lanes. Extremely difficult siting situations may involve mathematical modeling and consultation with the MLS Associate Program Manager for Engineering, ANN-150.

SECTION 1. AZIMUTH STATION

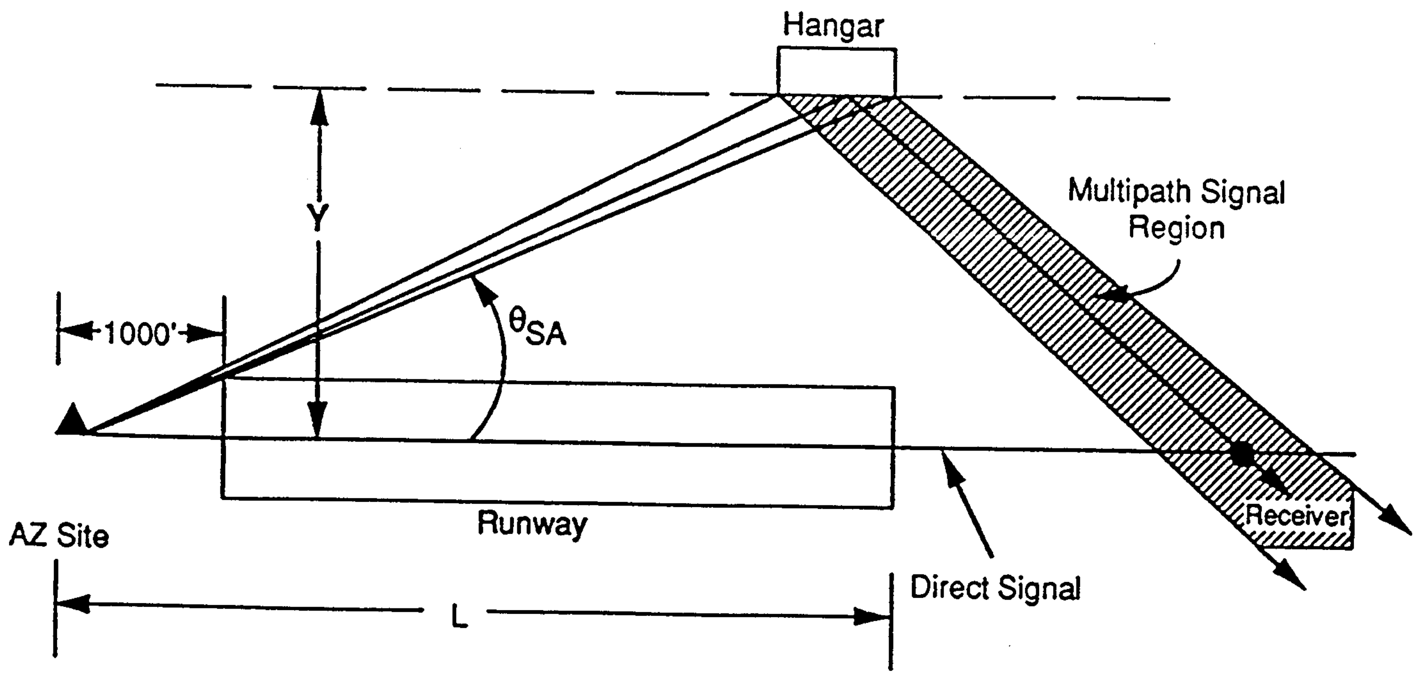
601. MULTIPATH. Any objects in line-of-sight of the AZ antenna and within the guidance region are potential multipath sources. Since the wavelength at the MLS frequency is about 2 inches, almost any concrete or metal surface can reflect, diffract, and/or shadow the MLS scanning beam. Smaller reflecting objects can cause narrow bursts of multipath as the receiver moves through the approach zone, but since the receiver is designed with acquisition and validation circuits to acquire the strongest and most persistent signal, the MLS will resist these bursts of short duration.

a. Large Buildings. The greatest multipath threat is from large buildings such as hangars, control towers, and hillsides. These large obstacles can reflect the scanning beam over a wide volume. However, the potential for guidance error exists only when the approach path passes through the multipath-affected region of space and the separation angle between the approach path and the reflecting surface is 1.7 beamwidths or less (figure 6-1). Using the equation in figure 6-1, if the beamwidth of the antenna to be used is equal to or less than the value resulting from the calculation, the multipath will be out-of-beam and is not a concern. This separation angle is the angle between the direct approach path and the obstacle. The magnitude of the guidance error reflection signal is a function of several factors, including the reflecting properties of the offending surface.

b. Out-of-beam Multipath. Out-of-beam multipath can cause guidance errors, particularly if the direct signal is shadowed by a building, vehicle, hill, or runway hump. For siting purposes, however, in-beam multipath constitutes the major problem and is more easily correctable.

c. Ray Tracing. The bounds of the multipath-affected region of space may be determined by ray tracing. Figure 6-1 shows the plan view of a building which is acting as a smooth reflector for the azimuth scanning beam. A ray is drawn from the azimuth antenna phase center to the extremities of the object; in this case, the corners of the building. The rays form an angle (θ_i) with respect to a perpendicular to the surface at that point. Then the reflected ray is drawn such that the angle between the reflected ray and the perpendicular (θ_r) is equal to θ_i. This yields the region of space in the plane parallel to the airport surface that contains the multipath disturbance. The vertical bounds of this region may be found by repeating this process for the elevation view (figure 6-2).

FIGURE 6-1. AZIMUTH BEAMWIDTH CRITERIA



$$\theta_{BW} \leq \left(\frac{Y}{1.7L}\right)\left(\frac{180}{\pi}\right) \text{ Degrees}$$

d. Multipath-induced Error. For a given approach path, multipath-induced guidance error is possible if the path traverses this region and, at the same time, the separation angle is 1.7 beamwidths or less. It should be noted that a diffracted signal will exist on either side of the bounds of this region.

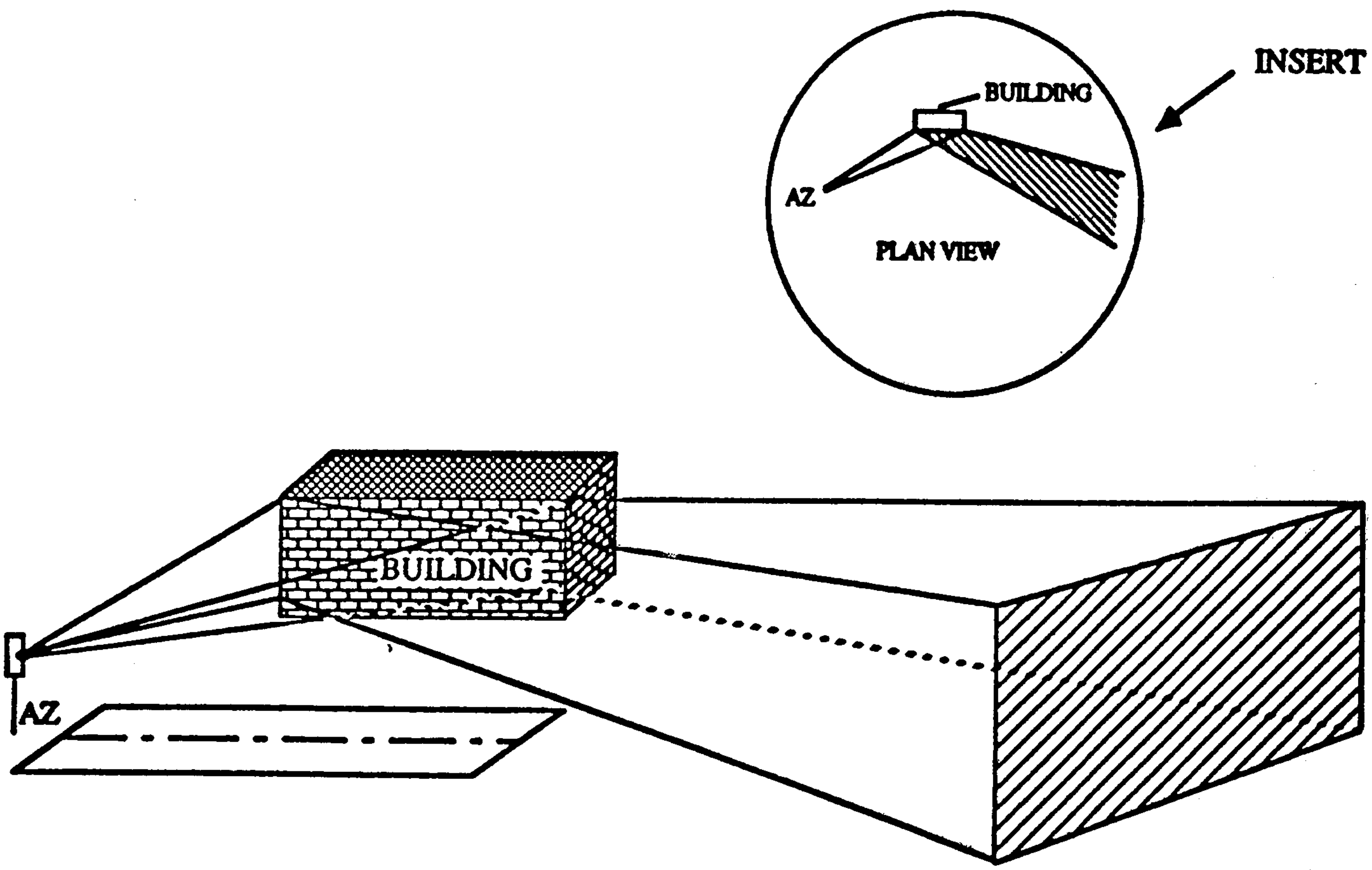
e. Multipath Error Formula. The peak in-beam multipath error depends on several factors. The peak error can be estimated using the formula:

$$E = \frac{\rho\theta_{BW}}{2\sqrt{g}} \sin\left[\frac{57.3\pi\ \theta_{SA}}{1.7\theta_{BW}}\right]$$

where:

E	= peak error (Degrees)
θ_{SA}	= multipath separation angle from direct signal as viewed from the ground antenna (<1.7 beamwidths)
θ_{BW}	= antenna beamwidth
g	= $\frac{\text{data rate}}{2 \times \text{FNB}}$; if f > 1.6 Hz
	= 1 ; if f < 1.6 Hz
FNB	= output filter noise bandwidth
	= 1.6 π/2 Hz
data rate	= 13 Hz (Azimuth); 39 Hz (High Rate Azimuth and Elevation)
ρ	= ratio of multipath to direct signal level
f	= multipath scalloping frequency (Hz)
	= $(V/\lambda)(\cos\alpha - \cos\beta)$
V	= aircraft velocity (nominally 200 ft/sec)
λ	= wavelength (0.2 ft)
α	= angle between the aircraft direction and the guidance antenna as viewed from the aircraft
β	= angle between the aircraft direction and the reflected signal as viewed from the aircraft

FIGURE 6-2. RAY TRACING TO DETERMINE MULTIPATH REGION
(ELEVATION VIEW OF INSERT)



f. Reflection Factors. The ratio of multipath to direct signal level (r), is a function of many factors. Some of the more dominant include reflector size, surface contour, polarization, surface roughness, the reflection coefficient of the reflecting material, and the angle at which the multipath signal is incident upon the reflector. A large, flat, metal building may create a situation where r may be 1 or greater, while for a smaller corrugated surface, r may be close to zero.

g. Modeling. To give the siting engineer a quantitative feel for the type situation that warrants concern about multipath, computations were performed using the MLS computer model. A perfectly reflecting smooth building face of dimensions 500 feet by 60 feet was placed alongside the runway and the CMN was calculated as a function of aircraft position for a 3-degree centerline approach (a beamwidth of 3 degrees was chosen to better illustrate the concepts). For a given building location, the largest CMN value was recorded; this procedure was followed many times as the building was moved about various points on a grid, using the model. The result is the contour map in figure 6-3 which represents the peak CMN value induced by the 500' x 60' building face centered at that location alongside the runway. Path following errors were too small to yield a meaningful contour map. Note that the induced errors are small when the building lies out-of-beam, but they increase as the building is placed closer to the runway and the multipath becomes in-beam, as evidenced by the steep contours at locations near 2,500 feet from the stop end.

h. Larger Reflectors. For comparison purposes, the same procedure is repeated in figure 6-4 using a 1000' x 100' building. The larger reflecting surface obviously induces larger CMN errors, some of which are significant.

i. Scattering. If the reflecting surface is corrugated, the signal may be scattered at other angles in addition to the one defined by the law of specular reflection ($\theta_r = \theta_i$). If d is defined to be the periodic spacing of the corrugations (in cm), the additional scattering angles (θ_R) are determined by the equation $\sin \theta_R = \sin \theta_i + 6R/d$ where θ_i is the angle of incidence and R represents all integers such that $|\sin \theta_R| < 1$. However, there is no simple method for determining the amount of incident energy that will be scattered in any direction.

j. Procedure. If a large reflecting obstacle lies within line-of-sight of the AZ antenna inside the guidance volume, take the following steps:

(1) Trace rays to determine the bounds of the multipath affected region. Given this and the approach path geometry, determine whether the multipath is in-beam (separation angle 1.7 beamwidths or less).

FIGURE 6-3. CONTOUR MAP OF PEAK CMN INDUCED BY A 500' X 60' BUILDING

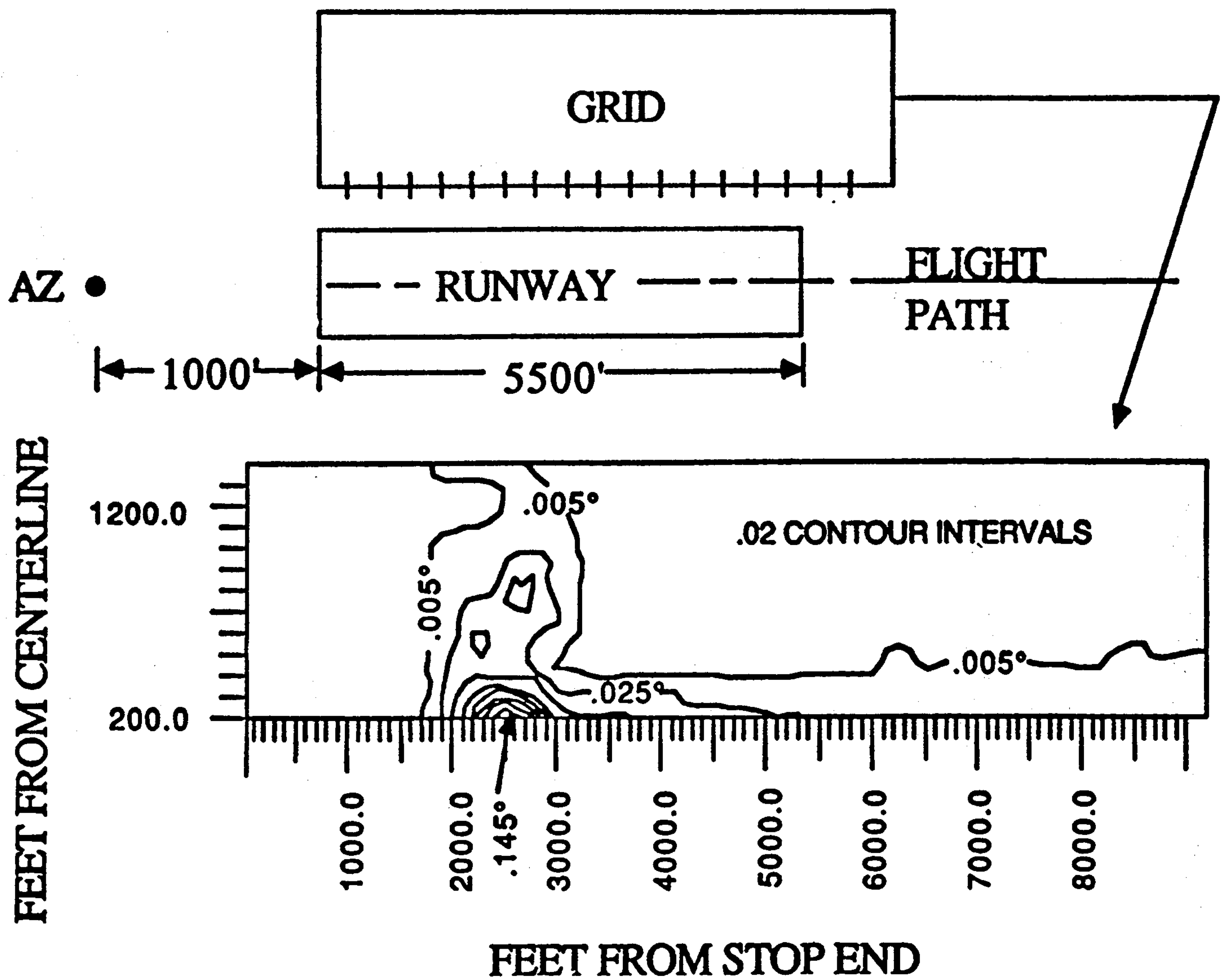
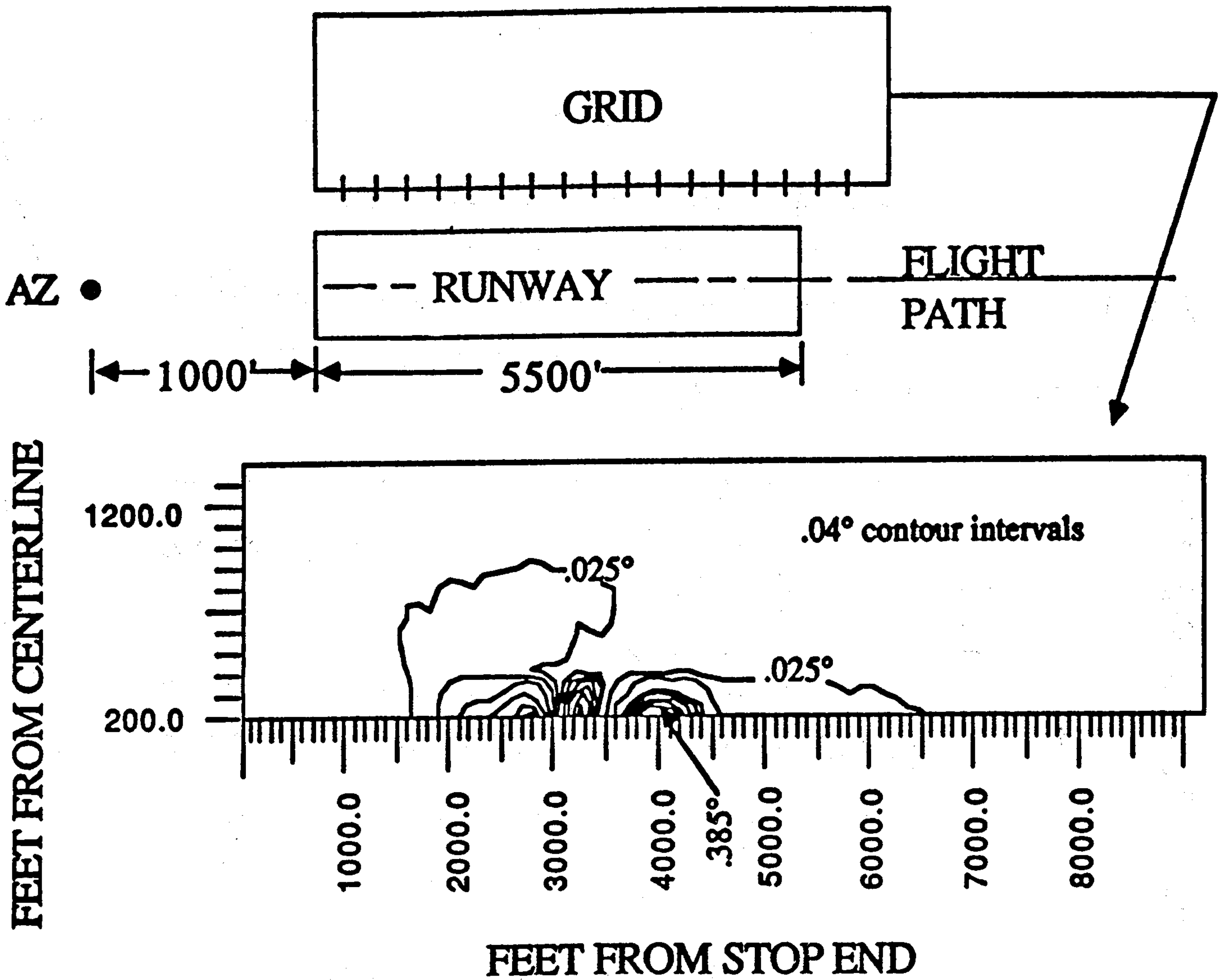


FIGURE 6-4. CONTOUR MAP OF PEAK CMN INDUCED BY A 1000' X 100' BUILDING



(2) If in-beam, and from a large structure, it may be advisable to use the MLS computer model to estimate the magnitude of the disturbance to help determine if a more narrow beamwidth should be used. The model indicates that buildings 100 feet wide can cause measurable error (.04 degrees CMN and .02 degrees PFE) if the multipath is in-beam.

602. SHADOWING FROM BUILDINGS, OBJECTS, AND TERRAIN. The performance of MLS in a region which is shadowed depends upon many factors including the geometry of the situation and the time elapsed during the absence of the signal.

a. In the case where the signal is completely blocked, the receiver should coast through the interruption for time periods up to 1 second.

b. Usually there is not a complete absence of a signal, but there exists an attenuated diffracted signal. Sufficient signal-to-noise ratio margins have been designed into the system so that MLS receivers are usually sensitive enough to acquire this diffracted signal. The error that results in a region of diffraction depends upon the orientation of the shadowing object.

(1) In the case of AZ shadowing, if the discontinuity of the shadowing object runs horizontally (the top of a building, for example), the separation angle is zero and there will be no guidance error as long as the diffracted signal is strong enough to be acquired. If the diffracting edge is vertical, the error can be large.

(2) In the case of EL shadowing, if the discontinuity of the shadowing object runs vertically (the side of a building, for example), the separation angle is zero and there will be no guidance error. If the diffracting edge is horizontal, the error can be large.

c. If there exists a multipath signal reflected from another obstacle within the shadowed region, the guidance error depends upon the acquisition history. If the receiver has been tracking the signal for more than 20 seconds before attenuation, the multipath will have no effect for at least 10-20 seconds. If there is no track history, the receiver may lock on to the multipath signal and cause large errors. This has been demonstrated in a situation where the direct signal was shadowed by a grove of trees and the receiver acquired the multipath signal reflected from a building. Scan limiting, OCI antennas or designing the approach paths above the shadowed region will resolve this situation.

d. It is important to identify regions of space in which the direct signal is shadowed. This is most effectively done using a phototheodolite placed at the AZ site under consideration. A skyline survey should be taken through 360 degrees to record site details including angle and distance of skyline and to identify areas in which azimuth coverage may be shadowed. It also allows determination of the size and location of all large buildings or terrain features which could be possible causes of azimuth multipath and/or shadowing.

603. RUNWAY HUMP SHADOWING. In addition to buildings and terrain, humped runways may cause shadowing, particularly near the threshold region.

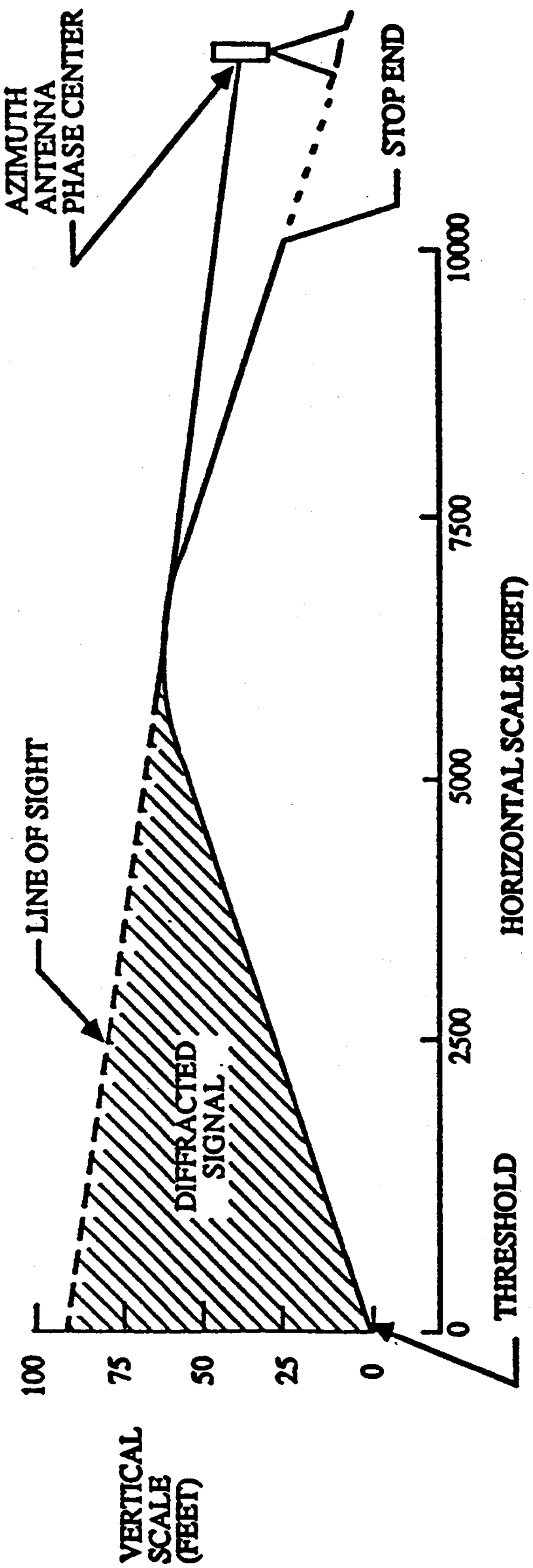
a. As shown in figure 6-5, the hump causes a region where the direct signal is shadowed. The AZ antenna should be sited such that adequate signal is provided throughout the runway region at a height of 2.5 m (8 ft.). It is not necessary that line of sight from the AZ antenna be achieved throughout the coverage region. Field measurements have shown that a significant amount of signal is diffracted over the hump into the shadow region. Computer models have been developed that accurately predict signal levels for these type of siting situations. The models can be used to determine the minimum height the AZ antenna needs to be placed in order to achieve the desired coverage.

b. In some cases it may be necessary to raise the height of the antenna a significant amount to provide the required power density. However this may not be possible due to violation of obstacle clearance criteria or light lane penetration. If this is the case then the runway coverage requirements can be relaxed. The first relaxation to be made involves the power density requirements of the azimuth angle transmission. They may be relaxed in accordance with FAA-STD-022, Microwave Landing System (MLS), Interoperability and Performance Requirements. If full coverage still cannot be achieved, the lower coverage limit may be raised as shown in figure 6-7. At threshold, coverage may be reduced to a height whose EL angle is equal to 0.6 of the minimum glidepath angle. This reduced coverage can extend to the datum point. In the remainder of the runway region, the coverage should only be reduced if the runway will not be used for Category III operations. If it is a potential Category III runway, then every effort should be made to maintain coverage to 2.5 m (8 ft.) from the datum point throughout the remainder of the runway.

604. COLLOCATION OF AZIMUTH AND LOCALIZER. The following guidelines are to be used to locate the AZ station with a localizer. The three siting possibilities are considered -- in front of, behind, or alongside the existing localizer.

a. Azimuth antenna sited in front of localizer antenna. The AZ station should be sited symmetrically on the localizer course centerline at least 30 m (100 ft.) ahead of the localizer array. The limit for the maximum distance (variable "X" in figure 6-6) is

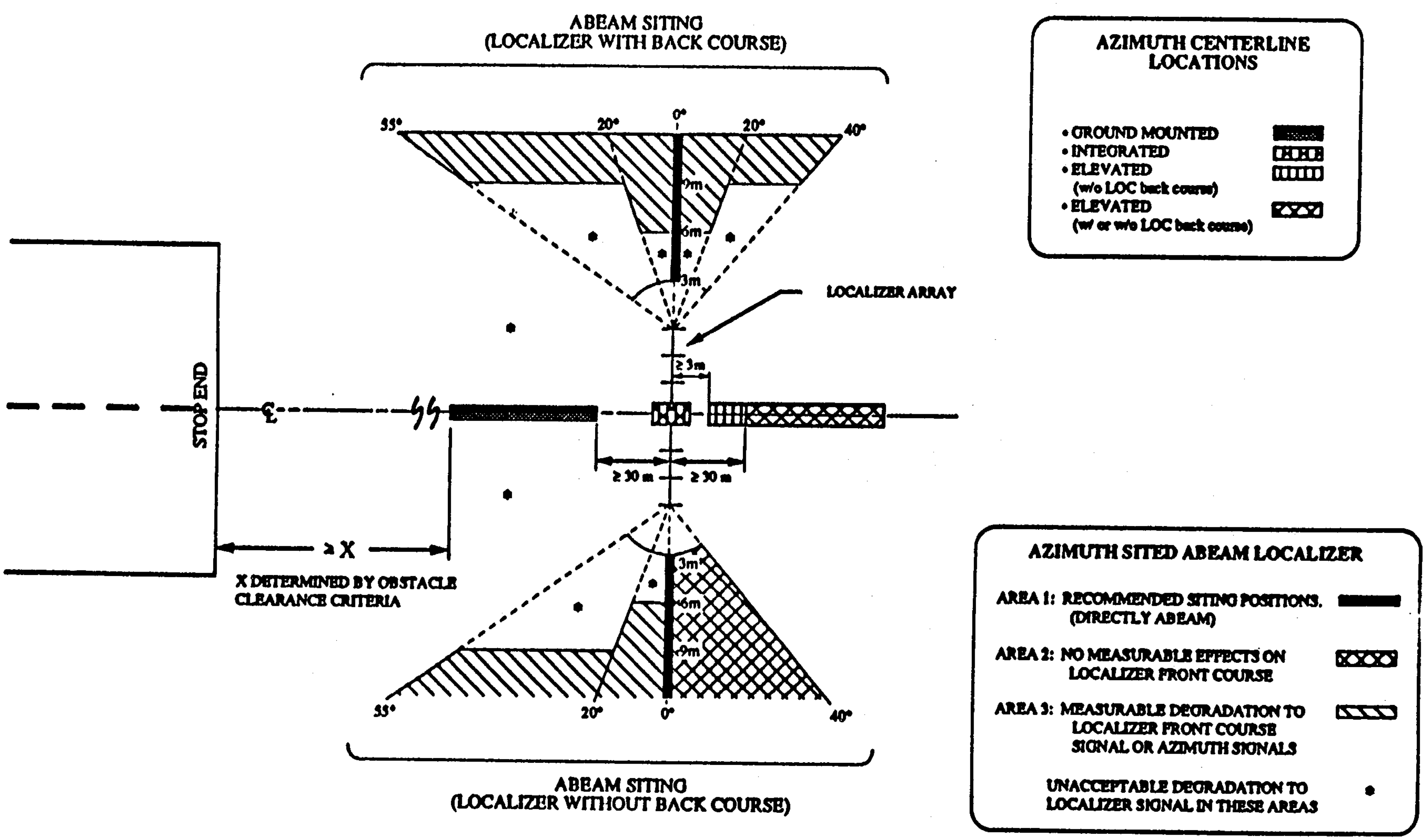
FIGURE 6-5. AZIMUTH SIGNAL DIFFRACTION BY A HUMPED RUNWAY



determined by the requirement to satisfy obstacle limitation requirements for both the AZ antenna and field monitor. This is the preferred location for the AZ antenna. However, the AZ antenna should not be sited such that it blocks line of sight between the localizer and its field monitor or between the localizer and the ILS ground check points. The ground check point on centerline will have visual line of sight blocked, but testing has shown minimal effect on the ground check itself. It is desirable to locate the DME/P antenna with the AZ antenna whenever possible. However, if siting the DME/P antenna at that location would violate obstacle limitation requirements, a lower antenna height could be considered if coverage at low heights near threshold is not required operationally. Otherwise, an offset DME/P antenna site or an alternate collocation configuration should be considered. Wherever possible, the AZ antenna location should be adjusted to minimize the effect on operations of the AZ antenna critical area. In addition, it may be desirable to maximize the commonality of the AZ and localizer critical areas. Due to the necessity of locating the AZ antenna in close proximity to the localizer, normally one of the antennas will have to be sited in the critical area of the other. For the AZ antenna critical area, see paragraph 503. The localizer critical areas should be obtained from local operations personnel.

b. Azimuth antenna sited behind the localizer. If the localizer is close to the stop end and mounting the AZ antenna in front of it would violate obstacle clearance requirements, or if problems with approach light systems require the AZ antenna to be tower mounted, an AZ antenna location behind the localizer should be considered (see figure 6-6). The required separation between the localizer and the MLS AZ antenna will depend on obstacle clearance requirements, availability of real estate, the presence of a localizer back-course, and the desirability of collocating the DME/P antenna with the AZ antenna. If a localizer back course does exist, a separation of at least 30 m (100 ft.) between the AZ and localizer antennas is recommended, and the AZ antenna must be sited symmetrically on the localizer course center line. For localizer antennas with a high front-to-back power ratio, it may be possible to reduce the separation to a minimum of 3 m (10 ft.). Once the separation between the AZ antenna and the localizer has been determined, the required height of the AZ antenna phase center relative to the top of the localizer radiating elements can be found from figure (6-7). Normally, to determine the value of "H," point "W" is selected to be at 2.5 m (8 ft.). The value for "H" is then computed according to the equation given. If selection of that point results in an AZ antenna height which violates obstacle clearance criteria or penetration of the light lane, a new point "W" may be utilized. The maximum height for "W" should be no greater than "A," which is at 0.6 of the minimum glidepath angle. It is desirable that the height of "W" be as close to 2.5 m (8 ft.) as possible. This will ensure the maximum amount of coverage meeting both the power density and accuracy requirements. If a localizer near field monitor is present on the extended runway center line, adjustment of

FIGURE 6-6. COLLOCATION OF AZIMUTH AND LOCALIZER ANTENNAS



the AZ antenna phase center height or the localizer monitor height may be required to minimize the effects of the localizer monitor pole on the azimuth signal. However, it is expected that, as long as the monitor pole is no higher than the localizer antenna element, no further increases in azimuth height would be required.

c. Azimuth antenna sited abeam the localizer. For this collocation configuration, the preferred siting is with the AZ antenna radome on the axis of the localizer array (area 1 of figure 6-6). A minimum separation of three meters (10 feet) between the AZ equipment and the localizer array end element is recommended. Where siting the AZ antenna on the axis of the localizer array is not practical, an AZ antenna site behind the axis of the array (area 2 of figure 6-6) would be the second option. The AZ antenna offset should be large enough to provide at least a three-meter (10-foot) separation and to avoid penetration of the azimuth proportional guidance region by the localizer array. Where the AZ antenna must be sited ahead of the localizer array axis, derogation of the localizer signal may result. This degradation should not be excessive with the AZ equipment located in area 3 of figure 6-6. However, this AZ antenna location should be verified using an equipment mock-up.

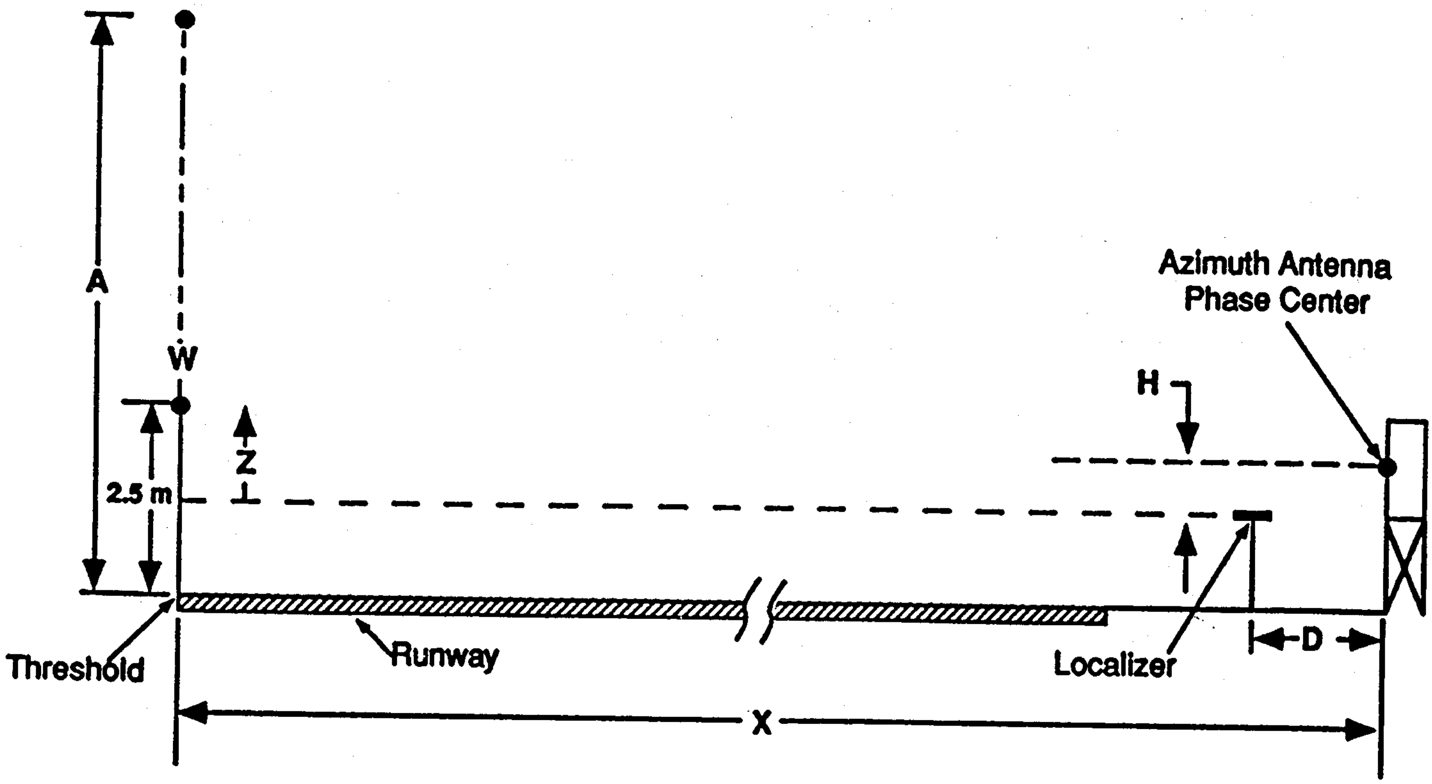
605. COEXISTENCE WITH APPROACH LIGHT SYSTEM AND OTHER OBJECTS IN THE NEAR FIELD OF THE AZIMUTH ANTENNA. Small shadowing objects such as chain link fences and power lines in the far field of the MLS antennas have negligible effect on performance. Such objects may introduce error; however, if they are within the near field. The distance from the antenna which defines the far field/near field boundary is given by:

$$\text{Far Field Boundary} = 2D^2/\lambda$$

where D is the longest dimension of the antenna (the diagonal for a rectangular aperture, or the length for a line array) and λ is the wavelength. For example, the far-field boundary is about 371 feet for the 2-degree AZ antenna, and 1,485 feet for the 1-degree AZ antenna.

a. Near Field Objects. Experiments have shown that metallic cylinders as thin as 4 inches placed 200 feet away on boresight from the AZ antenna can cause significant error. If possible, remove objects from the near field and minimize the width of any that must remain.

FIGURE 6-7. AZIMUTH ANTENNA CLEARANCE ABOVE ILS LOCALIZER



A = Height whose Elevation Angle is 0.6 times the Minimum Glidepath Angle
X = Azimuth Antenna to Threshold Distance
Z = Height of Point "W" above Localizer

$$H = \frac{3}{4}\left(1 + \frac{D}{X}\right)\sqrt{0.06D} - \frac{DZ}{X}$$

All Values in Meters

b. Approach Lighting Systems. If an approach lighting system exists or is planned for an opposite end approach, the preferred siting shall be on the runway centerline extended at a point greater than 200 feet beyond the last approach light bar to avoid infringement on the approach light plane.

c. Siting In Approach Lighting Systems. Where land acquisition or multipath/shadowing problems make siting beyond the light lane infeasible, the station may be sited within the light lane (see Order 8260.36). The top of the station, excluding the obstruction lights and air terminal, shall not penetrate the imaginary plane which is described as follows: the interior 800 feet of the approach light plane measured from the runway threshold; then outbound at a 7:1 slope to a point 5 feet above the light plane and continuing outbound at a height of 5 feet above the light plane to Station 15+00; then outbound at a 7:1 slope to a point 10 feet above the light plane and continuing outbound at a height of 10 feet above the light plane to a point 200 feet beyond the last light bar (see figure 6-8). This criteria shall apply to siting in lighting systems supporting all categories of approaches. (See Order 6850.2, Visual Guidance Lighting Systems, which may contain additional guidance.)

d. Siting Information. If siting in the light lane, the AZ antenna shall be located on extended runway centerline as far as possible from the nearest light station toward the runway stop end. This places the back of the AZ equipment against a light station. The AZ antenna phase center should be as high as possible with respect to the closest lightbar. This is limited, however, by the light plane penetration criteria and by the visibility requirement in Order 6850.2. This requirement states that the AZ antenna must not block the direct line of sight from the clear vision point to the relevant Approach Lighting System (ALS) station. The clear vision point is located 1,600 feet beyond the light lane length at a height determined by projecting an angle of glideslope minus 0.5 degrees from the ground point of intercept (GPI). It is at this point that line of sight must be maintained to the light station possibly affected by the proposed AZ site (see figure 6-9).

e. Minimum Phase Center Height. The AZ antenna should be installed as high as possible without violating the imaginary light lane plane. If the light station spacing is 100 feet or more, the AZ antenna phase center shall not be lower than 6 inches above light centerline of the closest light station toward runway stop end. If the light station spacing is less than 100 feet, the AZ antenna phase center shall be at least 2 feet above light centerline of the closest light station toward runway stop end.

<u>FIGURE 6-8. AZIMUTH SITING IN THE ADJUSTED LIGHT PLANE</u>

AZIMUTH SITING ALLOWED: NOT TO PENETRATE ADJUSTED LIGHT PLANE

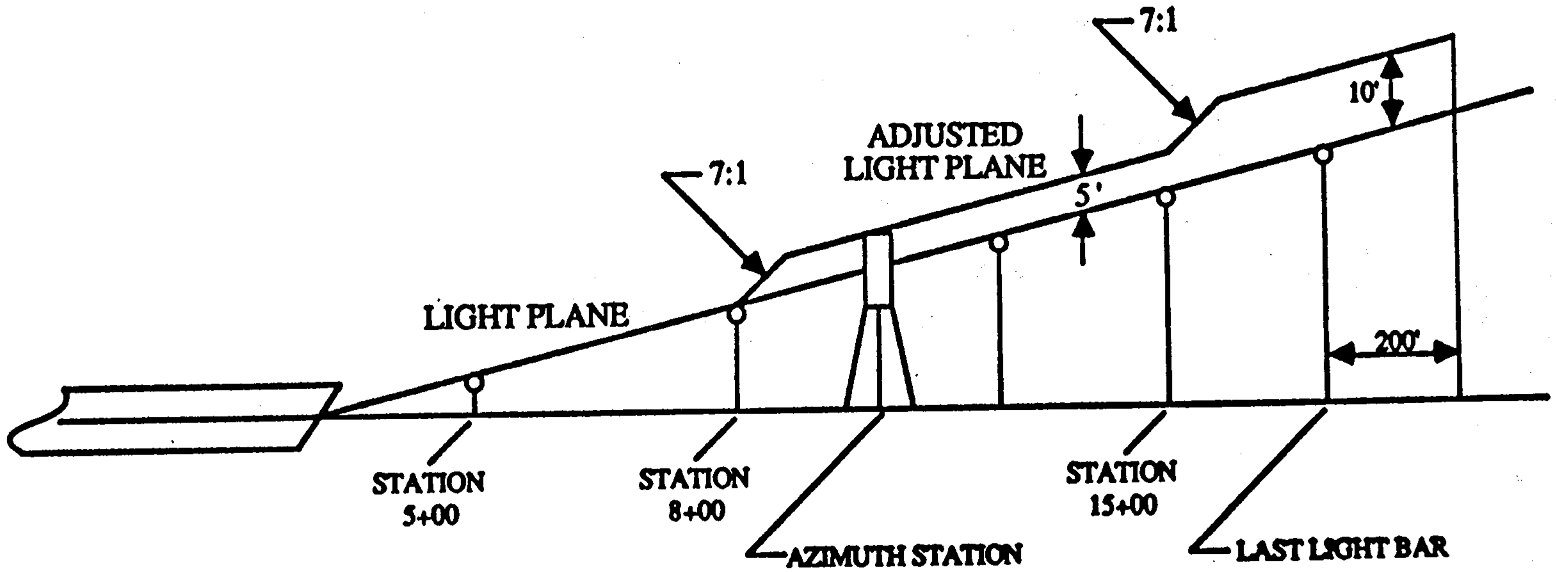
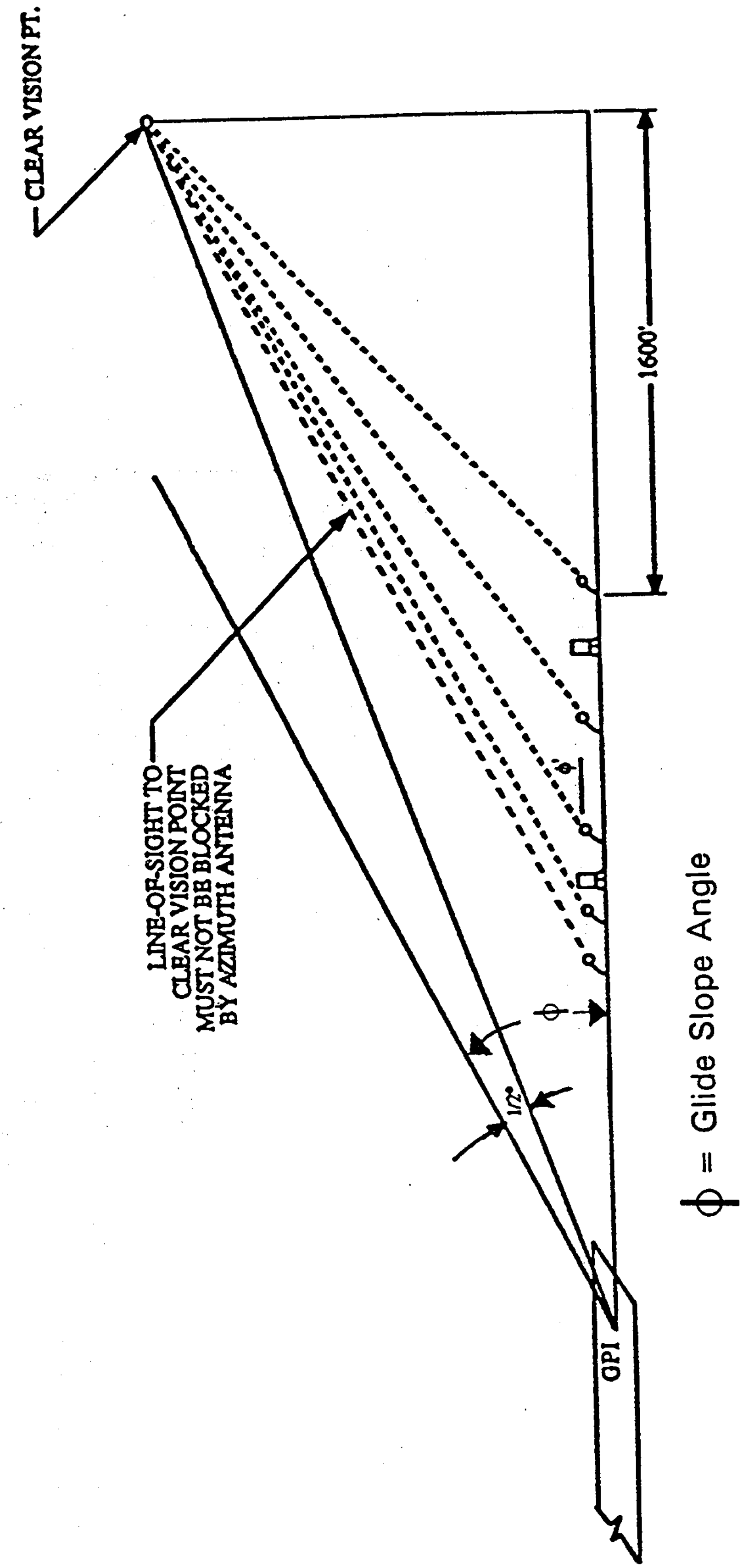


FIGURE 6-9. VISIBILITY CRITERIA OF THE LIGHT PLANE



SECTION 2. ELEVATION STATION

606. MULTIPATH. The concepts presented in paragraph 601 for azimuth multipath also hold for elevation multipath.

a. Rising Terrain. Rising and/or discontinuous terrain in the approach region constitutes the largest threat. Since a shift in the EL antenna location will not usually help in this situation, the use of a more narrow beamwidth is the more likely solution.

b. In-beam Multipath. Figure 6-10 gives the formula for calculating the separation angle for a reflection from terrain rising at an angle slope given the glidepath angle (θ_{EL}) and the EL antenna phase center height H. If the EL antenna beamwidth is less than or equal to this separation angle divided by 1.7, the multipath will be out-of-beam. The use of a more narrow beamwidth system reduce the amount of in-beam multipath. In addition, all multipath errors will also be reduced in proportion to beamwidth.

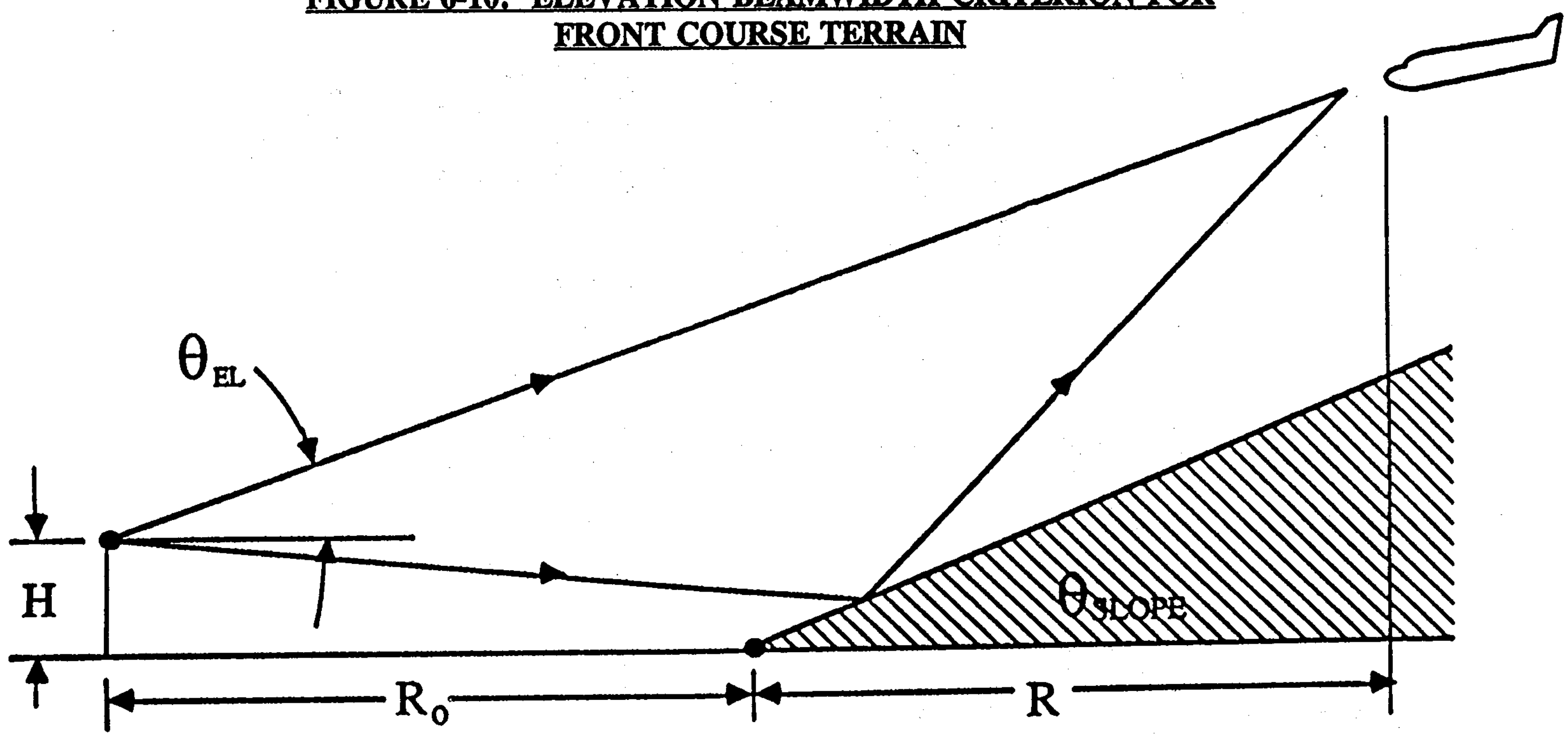
c. Reflectivity. Although figure 6-10 appears to indicate the reflected energy emanating from a singular specular point, a fairly large reflecting surface area (several thousand square feet or so) is required to produce significant errors due to multipath. The presence and nature of any vegetation or tree cover will also reduce the reflectivity of the sloping terrain.

d. Sidelobes. Since there is always a reflection of antenna sidelobes from a flat airport surface, EL antennas are designed to have low sidelobes at the lower scan angles.

607. SHADOWING. The comments made in paragraph 602 for azimuth signal shadowing also apply for elevation signal shadowing. However, for the EL case, objects whose discontinuities are vertical will not cause guidance error if the diffracted signal is acquired, but horizontal discontinuities may. All efforts should be made to site the antenna so that shadows are not introduced into important volumes of airspace, or avoid approach paths which pass through shadowed areas. As was the case at the AZ site, phototheodolite survey measurements are made from the tentative EL sites to make terrain profile measurements and identify areas in which EL coverage may be reduced.

608. COLLOCATION OF THE ELEVATION AND GLIDESLOPE ANTENNAS. The EL antenna will, in most collocation situations, be located forward of the ILS glideslope antenna. To minimize derogation of the ILS signal structure, the EL station must be sited in the following manner.

FIGURE 6-10. ELEVATION BEAMWIDTH CRITERION FOR FRONT COURSE TERRAIN



$$\theta_{SA} \approx 2 \left[\theta_{EL} + \left(\frac{180}{\pi}\right) \frac{H}{R_o + R} - \frac{R\,\theta_{SLOPE}}{R_o + R} \right]$$

$$\theta_{BW} < \frac{\theta_{SA}}{1.7}$$

NOTE: All angles are in degrees

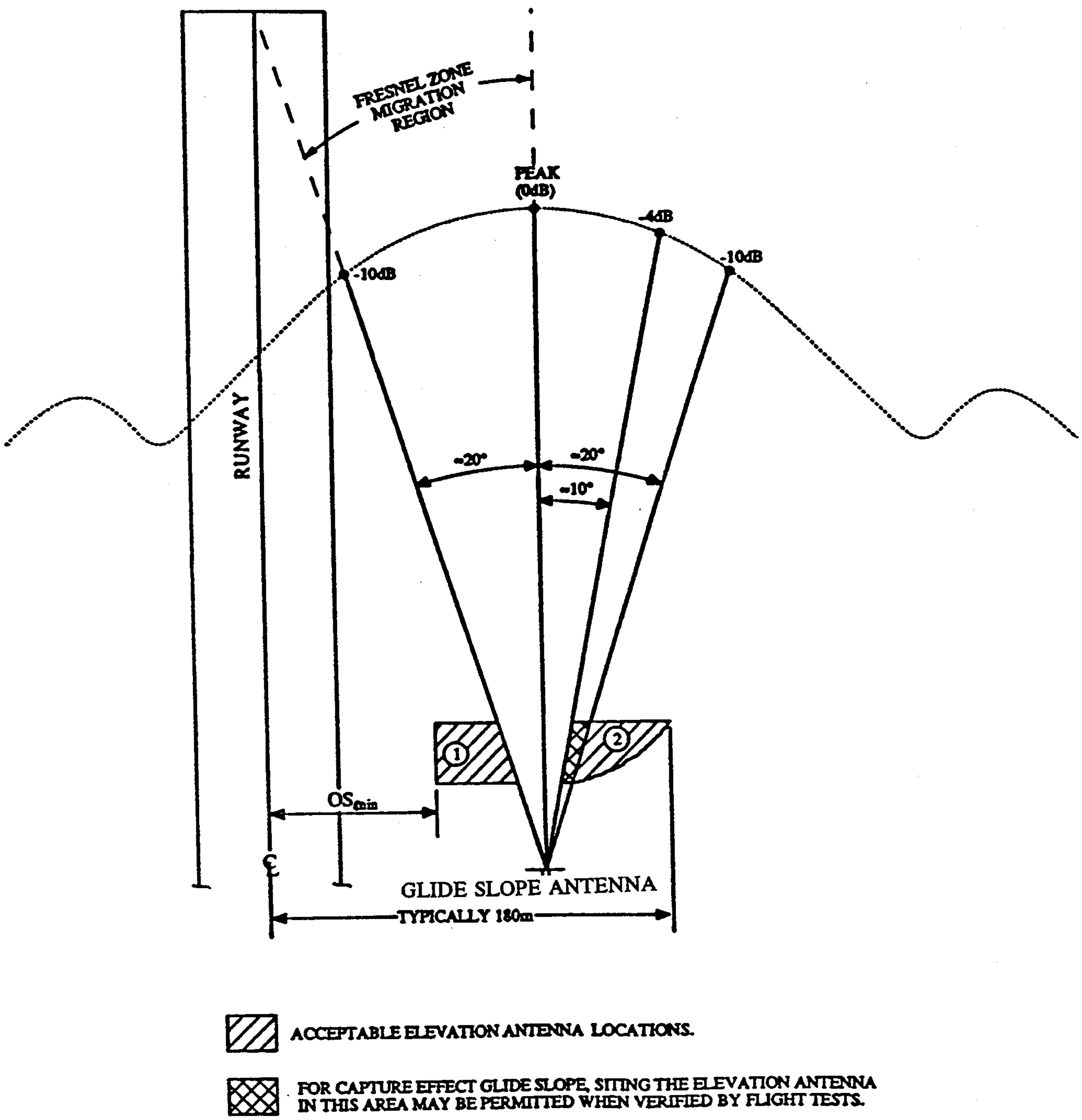
a. <u>Elevation Station Setback</u>. When collocated, it is recommended that the EL antenna setback be such that the MLS and ILS approach reference datums coincide within 3 feet. This assumes that the glideslope is sited such that the height of the ILS reference datum meets the recommendations of Order 8260.34, Glide Slope Threshold Crossing Height Requirements. Since the phase center of the EL antenna is higher than the glideslope phase center, the EL antenna will always be sited forward of the glideslope where coincident reference datums are desired. This will place the EL antenna in the glideslope critical area; the effect on the glideslope signals can be minimized by proper selection of the EL antenna offset from runway centerline.

b. <u>Elevation Station Offset</u>. Studies indicate that the EL antenna's angular position relative to the glideslope antenna pattern is a more important factor in successful ILS/MLS collocation than is the distance between the two antennas. Figure 6-11 indicates the validated regions in the vicinity of the glideslope antenna where the EL antenna may be sited without significant effect on the glideslope signals. Choosing an EL antenna site outside those regions would make flight testing with MLS mockups a necessity prior to installation. If the EL antenna is to be sited on the runway side of the glideslope, the effects on the glideslope signal may be minimized by siting the EL station on the runway side of the diagonal line between threshold and the glideslope antenna. The limiting factor on siting between the glideslope antenna and the runway is the proximity of the EL station to the runway safety area and the obstacle free zone criteria of AC 150/5300-13. Alternately, the EL station can be sited outside the glideslope antenna. Tests indicate that satisfactory glideslope performance is obtained if the EL station is sited so that it lies in a region of the glideslope horizontal radiation pattern which is at least 10 dB down from the maximum. For the Mark 1F sideband reference glideslope, this region is at an angle of 20 degrees or more in AZ from the pattern maximum. For other glideslope equipment designs, particularly the capture-effect designs, the -10 dB value may be relaxed to -4 dB as long as the glideslope signal quality is verified. The increased curvature and height above runway threshold of the MLS glidepath should be taken into account when siting the EL antenna outside the glideslope antenna (see paragraph 507).

SECTION 3. DISCUSSION OF COMPUTER MODELING TO AID IN SITING

609. <u>COMPUTER MODEL OF THE MLS</u>. A computer model of the MLS was developed for the FAA by the Lincoln Laboratory of M.I.T. to assess the effects of reflections and shadowing on system performance.

FIGURE 6-11. COLLOCATION OF ELEVATION AND GLIDESLOPE ANTENNAS



a. Two Models. The MLS model consists of two smaller models: the propagation model and the system model. The propagation model calculates the reflected and/or shadowed signal at all points along a given flight path. The system model then predicts the raw error along the flight path. All user defined parameters are read into the model via a formatted input file. Separate graphical display programs provide the plots for each of the models. Graphical displays of airport layout (including placement of user-defined objects), flight profiles, and multipath levels are provided for the propagation model output. The system model graphical display program plots raw dynamic and static errors, as well as PFE and CMN errors.

b. Modeling Information Requirements. If the siting engineer deems it necessary to model an airport scenario, the following information is needed as input to the model:

(1) The x, y, and z coordinates of the antenna type for the AZ, EL, and DME/P. The origin is defined to be the intersection of the centerline and the stop end of the runway. The x-y plane lies on the airport surface, with the positive x-axis lying on the centerline. The positive z-axis measures altitude and passes through the stop end of the runway.

(2) Up to 10 rectangular and 10 triangular plates representing specular ground reflection may be specified. Coordinates of three corners, surface roughness height, and complex dielectric constant are required.

(3) A total of 10 plates representing scattering and shadowing building surfaces can be specified. When necessary, each building can be represented by more than one plate. For each plate, it is required to know the coordinates of the corners, the surface composition, and the tilt of the building with respect to the vertical.

(4) A total of 10 scattering and 10 shadowing aircraft can be modeled. Each aircraft is specified by the x and y coordinates of the nose and tail, type of aircraft (B-747, B-707-320B, B-727, DC-10, C-124, Convair 880, or Hastings), and the altitude. Other aircraft may be modeled if necessary.

(5) The x, y, and z coordinates of the front, center, and back of a runway hump.

(6) The number of waypoints in the segmented approach, the x, y, and z coordinates of the end points of each segment, and the velocity of the receiver in ft./sec.

(7) Runway length and width, the coordinates of the MLS datum point, and the type of MLS antenna.

c. Additional Information. For further information on MLS modeling, contact the Airborne Systems Technology Branch, ACD-330, at the Federal Aviation Administration Technical Center, Atlantic City International Airport, New Jersey 08405.

610.-699. RESERVED.

CHAPTER 7. HELIPORT MLS SITING UNDER IDEAL CONDITIONS

SECTION 1. OVERVIEW

700. GENERAL. MLS equipment at a heliport should be sited so that the helicopter maneuver area (HMA) and the final approach reference area are coincident and that they are within coverage of the AZ, EL and DME/P signals. Furthermore, the HMA should be within proportional coverage of the AZ signal. This is an optimum siting which will provide guidance for straight in approaches to Category I minima. In addition, this siting will support future MLS enhancements. Although final positioning for radio navigational systems is not an exact science, this chapter identifies, as far as practical, the considerations and constraints that affect final placement of the MLS at a heliport.

701. COLLOCATED SITING. Due to limited real estate at most current and proposed heliports it is normally necessary to collocate the MLS AZ and EL equipment. A collocated system is defined as an installation where the AZ and EL antennas are separated by a distance less than 656 feet measured parallel to the final approach course. For noncollocated sitings at a heliport the siting criteria are the same as for a runway with a similar siting configuration.

SECTION 2. AZIMUTH ANTENNA

702. STATION LOCATION. The preferred location for the AZ antenna is between 375 and 656 feet beyond the center of the final approach reference area on the extended centerline of the approach.

a. Siting Considerations. Siting on the extended centerline will permit AZ course guidance to touchdown. This configuration will also allow for the use of an MLS signal for departure guidance. The minimum distance beyond the landing area is influenced primarily by the AZ antenna critical area. The minimum distance also provides the approach aircraft with an obstacle free space beyond the landing area in the event an "overshoot" is required.

b. Centerline Siting. All efforts shall be made to site the AZ antenna on the extended centerline of the approach.

c. Off Centerline Siting. If centerline siting cannot be accomplished due to lack of space, collocation with approach lights, or unsuitable terrain beyond the heliport, then the

AZ antenna may be sited anywhere in the AZ antenna siting area, as depicted in figure 7-1 and the approach will still be defined as a straight-in approach. In these cases the AZ antenna zero-degree guidance plane must parallel the extended centerline of the landing area. The preferred site is on the left side of the landing area centerline (as seen from the inbound approach point of view). This siting allows the pilot in command a better view of the final approach reference area from decision height.

d. Coverage Limitations. Depending on where the AZ antenna is sited in the allowable area, a portion or all of the final approach reference area will not be covered by a proportional guidance MLS AZ signal.

703. CRITICAL AREA. The critical area for the MLS AZ station is shown in figure 7-2. This area around the AZ antenna must be protected from the unlimited movement of surface traffic to ensure continuous integrity of the radiated signal.

a. Requirements. Paragraph 503a applies.

b. Area Definition. The critical area for the AZ antenna is defined as follows:

(1) The area contained by a line from the AZ antenna straight out along the selected inbound azimuth to a point abeam the monitor, direct to the monitor and back to the antenna.

(2) The area within 50 feet of the area defined in subparagraph 703b(1).

(3) The area has an upper surface extending 15 degrees above the horizontal from the antenna phase center.

(4) The lower surface is a horizontal plane 5 feet below the phase center of the antenna.

c. Limitations. No uncontrolled traffic or personnel are permitted within this area.

704. OBSTACLE CLEARANCE. Proper MLS siting is influenced by the necessity to meet obstacle clearance requirements. In addition to the requirements in the ground plane containing the final approach reference area, there are imaginary surfaces that rise at differing slopes from different points on the heliport that shall not be penetrated.

FIGURE 7-1. COLLOCATED MLS SITING

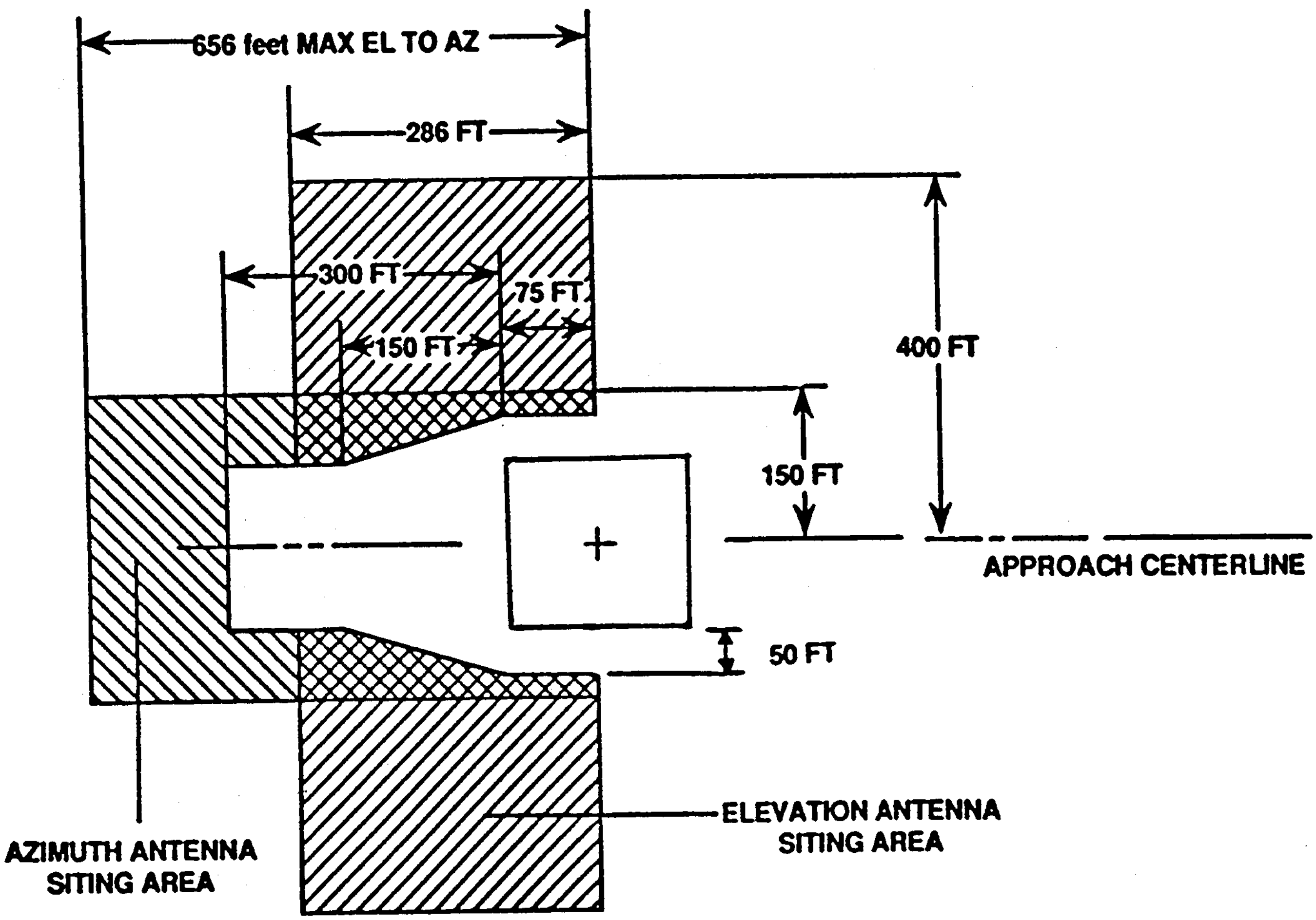
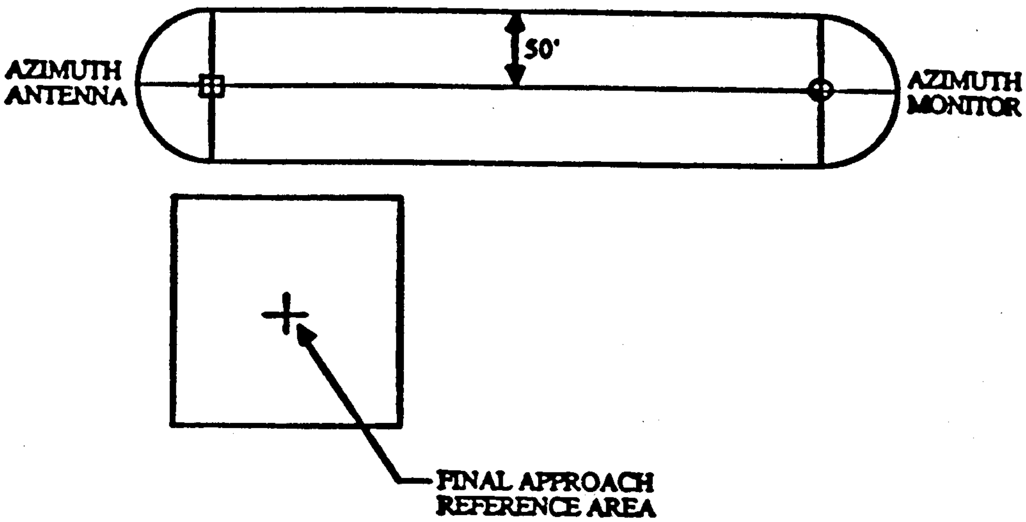
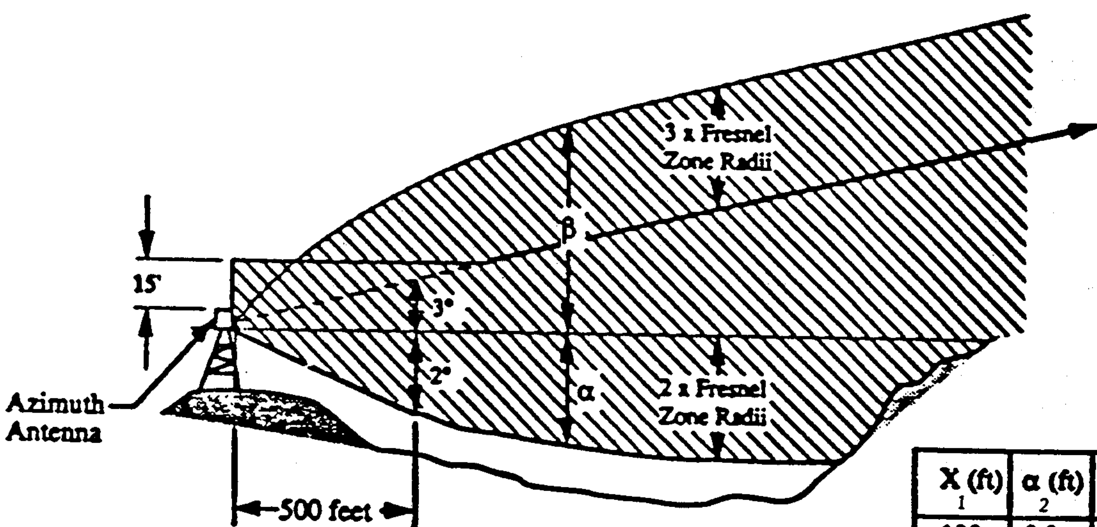


FIGURE 7-2. AZIMUTH ANTENNA CRITICAL AREA



a). PLAN VIEW



X (ft)[1]	α (ft)[2]	β (ft)
100	8.9	18.6
250	14.1	34.3
500	20.0	56.2
750	24.5	76.0
1000	28.3	94.8

Where:

$\alpha = 2\sqrt{2X}$

$\beta = X \bullet \tan 3° + 3\sqrt{2X}$

b). PROFILE VIEW

[1] Measured from Azimuth Antenna
[2] Measured from bottom of Azimuth Antenna Aperture

a. <u>If there is a visual approach</u> from the direction opposite to the instrument approach direction, then the relevant surface for an optimal siting of the AZ antenna is the 8:1 visual approach surface recommended in AC 150/5390-2, FAA Heliport Design. This surface begins at the helipad with the same width as the helipad. It extends outward and upward for a horizontal distance of 4,000 feet expanding uniformly to a width of 500 feet. It has a slope of 8 to 1 (see figure 7-3).

b. <u>For an azimuth site 300 feet</u> from the final approach reference surface, this results in an allowable antenna height of 37.5 feet. Therefore, even with a collocated DME/P antenna having a height of 22 feet (including lightning rod) the visual approach surface will not be violated. However, when the AZ antenna is located elsewhere within the AZ antenna siting area (figure 7-1) this surface would be violated. For example, an azimuth site 150 feet from the final approach reference area would have an allowable height of 18.75 feet. In this case the DME/P antenna would have to be sited separately to avoid penetrating the 8:1 approach surface.

c. <u>Obstruction Standards</u>. Paragraph 502 applies.

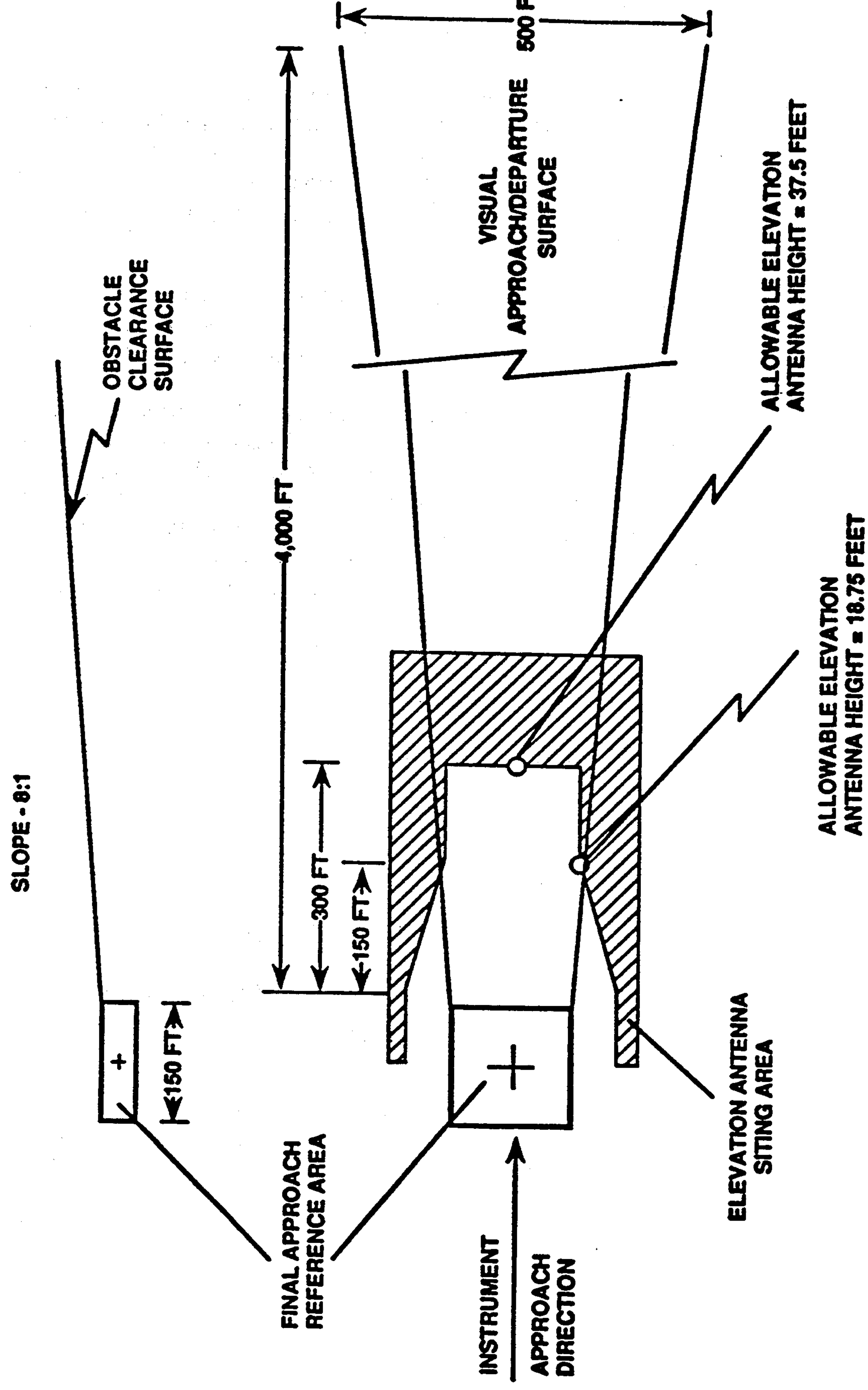
<u>SECTION 3. DME/P SITE</u>

705. <u>LOCATION</u>. The preferred location for the DME/P antenna is at the azimuth site. If the AZ-DME/P site is sited other than on the extended centerline or the heliport has two instrument approaches, then the DME/P antenna could violate obstacle clearance surfaces (Part 77). In addition, the DME/P antenna must be sited to ensure adequate signal at 8 feet above the final approach reference area (Reference FAA-E-2721B, page 59). The siting engineer should check the manufacturer's specifications for the antenna being installed and site the antenna to satisfy both requirements.

706. <u>ANTENNA OFFSETTING</u>. If the DME/P antenna cannot be sited on extended centerline, then it may be offset laterally. However, computed offset MLS approaches may not be possible with offsets of 400 feet or greater. In this case the aircraft avionics will be unable to use the DME/P information to calculate a computed centerline approach course. Subparagraphs 505a and 505b apply.

707. <u>DME/P MULTIPATH INTERFERENCE</u>. Subparagraphs 506a and 506b apply.

FIGURE 7-3. ELEVATION ANTENNA SITING WITH OPPOSING VISUAL APPROACH



SECTION 4. ELEVATION ANTENNA

708. ANTENNA LOCATION. The siting of the EL station antenna at a heliport is dependent upon the following: (1) the minimum glidepath angle, (2) the phase center height of the EL antenna, and (3) the antenna SB from the line perpendicular to the approach centerline and passing through the center of the final approach reference area (helipoint). Once these values are determined, acceptable OS from approach centerline can be found using the procedures in the following paragraphs.

a. Preferred Location. The preferred location of the EL antenna is offset 125 feet from the approach centerline abeam the helipoint. This siting will permit any approach angle above the minimum approach angle which is dictated by obstacles along the approach path.

b. Helipoint Crossing Height and Minimum Glidepath. The controlling limitation in siting the EL antenna is that the imaginary plane defined by the selected glidepath must cross the final approach reference area at a Helipoint Crossing Height (HCH) of between 8 to 15 feet (reference Order 8260.3, Terminal Instrument Procedures, chapter 11). Use formula 1 to determine the slope of the obstruction clearance surface (OCS) (TERPS, chapter 11). Then use table 7-1 to find the MGP from the OCS slope. Any slope value not shown in table 7-1 should be increased to the next higher value and the corresponding MGP used.

Formula 1: OCS slope = (H-(HCH-PCH))/(D-1150)

where:

H = Height of controlling obstacle (feet)

HCH = Helipoint Crossing Height (feet)

PCH = Phase Center Height (feet)

D = Distance from helipoint to controlling obstacle (feet)

NOTE: THE HEIGHT OF THE CONTROLLING OBSTACLE SHOULD BE THE HEIGHT OF OBSTACLE ABOVE THE HELIPOINT.

(1) Since the HCH may vary from 8 to 15 feet and the EL phase center can be adjusted by raising or lowering the antenna base, the siting engineer has some flexibility in siting the antenna. This flexibility is very useful in solving coverage/multipath problems and physical site limitations. Good engineering judgment is essential in selecting the final site.

TABLE 7-1. MINIMUM GLIDEPATH ANGLE ESTIMATE

Glide Path Angle (degrees)	Surface	Glide Path Angle (degrees)	Surface
3.0	34.0:1	6.0	17.0:1
3.1	32.9:1	6.1	16.7:1
3.2	31.9:1	6.2	16.4:1
3.3	30.9:1	6.3	16.2:1
3.4	30.0:1	6.4	15.9:1
3.5	29.1:1	6.5	15.6:1
3.6	28.3:1	6.6	15.4:1
3.7	27.6:1	6.7	15.2:1
3.8	26.8:1	6.8	14.9:1
3.9	26.1:1	6.9	14.7:1
4.0	25.5:1	7.0	14.5:1
4.1	24.9:1	7.1	14.3:1
4.2	24.3:1	7.2	14.1:1
4.3	23.7:1	7.3	13.9:1
4.4	23.2:1	7.4	13.7:1
4.5	22.7:1	7.5	13.5:1
4.6	22.2:1	7.6	13.3:1
4.7	21.7:1	7.7	13.2:1
4.8	21.2:1	7.8	13.0:1
4.9	20.8:1	7.9	12.8:1
5.0	20.4:1	8.0	12.7:1
5.1	20.0:1	8.1	12.5:1
5.2	19.6:1	8.2	12.3:1
5.3	19.2:1	8.3	12.2:1
5.4	18.9:1	8.4	12.0:1
5.5	18.5:1	8.5	11.9:1
5.6	18.2:1	8.6	11.7:1
5.7	17.9:1	8.7	11.6:1
5.8	17.6:1	8.8	11.5:1
5.9	17.3:1	8.9	11.3:1
		9.0	11.2:1

(2) If the EL antenna must be sited prior to the helipad due to obstacles, taxiways or other space limitations, then the Approach Surface Reference Point (the point located on the final approach course abeam and 8 feet below the phase center of the EL antenna) will be used as the reference point for obstruction and approach surface measurements in lieu of using the helipoint.

c. Antenna Setback. The EL antenna may also be setback from the center of the final approach reference area as shown in figure 7-1. However, the final siting must still provide for an HCH between 8 and 15 feet. In addition, a setback siting will limit the range of glidepath angles which can be used. The glidepath which would yield an HCH of 15 feet would be the maximum approach angle authorized. The maximum glidepath angle is found using the following equation:

GP = ARCTAN ((15-PCH)/SB)

where:

PCH = Phase Center Height (feet)

GP = Glidepath Angle

SB = Setback from Helipoint measured parallel to the final approach course centerline (feet)

d. Antenna Offset. The EL antenna may be sited offset up to 400 feet from the landing area extended centerline as shown in figure 7-1. At this distance or less the differences between the planar glidepaths and hyperbolic glidepaths are at a minimum (less than 10 feet). A detailed discussion on handling hyperbolic glidepaths is in chapter 5, section 4. For an EL antenna siting other than abeam the helipoint, the edge of the EL antenna siting area closest to the approach centerline in figure 7-1 is determined using the following decision algorithm:

If SB < 75'
Then MO = 125'

If 75' < SB < 225'
Then MO = ((225-SB) x .33 + 75')

If SB > 225'
Then MO = 75'

Where:

SB = Setback from helipoint measured parallel to the final approach course centerline

MO = Minimum Offset from extended approach centerline

(1) The minimum offset is influenced by the necessity to protect the antenna system from rotor downwash and engine exhaust, maintain clearance between the instrument approach lights and the antenna, and meet the surface requirements specified in AC 150/5390-2.

(2) Active taxiways, the potential of nearby objects for shadowing and reflecting, and available space should all be considered when determining which side of the landing area to site the EL antenna. When possible the EL antenna should be sited on the left side of the extended approach centerline (looking from the approach viewpoint).

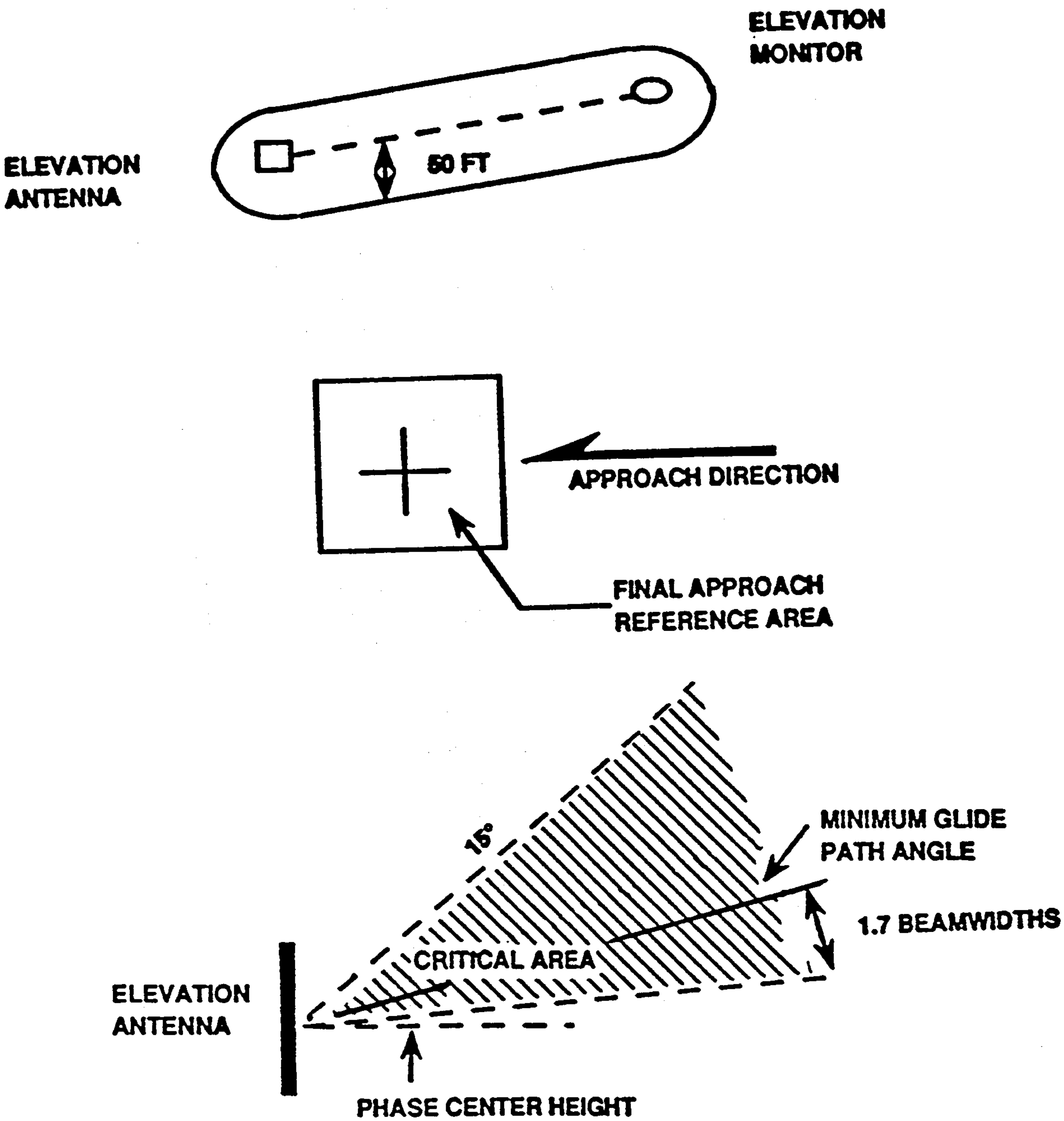
(3) The maximum offset is 400 feet from the extended approach centerline.

709. CRITICAL AREA. The critical area about the EL antenna consists of a 50-foot area either side of the centerline from the EL antenna to its monitor. The area includes a 50-foot radius about the EL antenna and the monitor antenna. The area has an upper surface extending 15 degrees above the horizontal from the antenna phase center. The lower surface extends 1.7 beamwidths below the minimum glidepath angle. The critical area is shown in figure 7-4. No uncontrolled traffic or personnel are permitted within this area.

710. OBSTACLE CLEARANCE. Proper MLS siting is influenced by the necessity to meet obstacle clearance requirements. In addition to those requirements in the ground plane containing the final approach reference area, there are imaginary surfaces that rise at differing slopes from different points on the heliport that may not be penetrated.

a. If there is a visual or nonprecision approach from the opposite direction to the instrument approach then the relevant surface is the 2:1 transitional surface specified in AC 150/5390-2. This transitional surface begins at the height of the approach surface (which increases at a slope of 8:1 outward along the approach centerline) and increases horizontally at a ratio of 2:1 to a width of 250 feet measured perpendicular to the approach centerline. It extends for a horizontal distance of up to 4,000 feet along the approach centerline until it is replaced by the 8:1 surface (see figure 7-5).

FIGURE 7-4. ELEVATION ANTENNA CRITICAL AREA



(1) When the EL antenna is offset 125 feet from the final approach extended centerline the allowable antenna height is 25 feet. Current production antennas do not exceed the allowable 25 foot height.

(2) For a site other than abeam the center of the final approach reference area, the 2:1 transition surface might be violated. For example, when the EL antenna is setback 207.6 feet from the helipoint at the minimum offset point (105 feet), the maximum allowable antenna is only 16.6 feet. In this case, the EL antenna may be tall enough to violate the visual approach surfaces (see figure 7-6).

b. Obstruction Standards. Paragraph 508 applies.

SECTION 5. FIELD MONITORS.

711. GENERAL. Paragraphs 509a through 509d apply.

a. Heliport Siting. If the EL and AZ antennas are sited side by side such that their signal coverage areas overlap, then both the AZ and EL monitors can be mounted on the same monitor pole. This will reduce the number of obstacles placed around a heliport.

b. Obstacle Clearance. Proper monitor siting is influenced by the necessity to meet obstacle clearance requirements. In addition to those requirements in the ground plane containing the final approach reference area, there are imaginary surfaces that rise at differing slopes from different points on the heliport that may not be penetrated.

(1) The relevant surface for monitor siting is the 300 foot wide obstacle free zone which begins at the helipoint elevation and continues out to 250 feet at helipoint elevation. Then it rises at a 20:1 slope to a height of 8 feet below HCH and remains at that elevation to 1,150 feet from the helipoint. This area must not be violated. In addition, a transitional surface extends perpendicular to this area at a slope of 7:1 (see figure 7-7).

(2) For example, an EL antenna sited abeam the final approach reference area, offset 150 feet from the extended approach centerline with a monitor placed at 30 degrees and 200 feet away would have a maximum allowable monitor height of 14.3 feet. This equates to monitoring a 2-degree EL signal.

FIGURE 7-5. HELIPORT APPROACH TRANSITION SURFACE

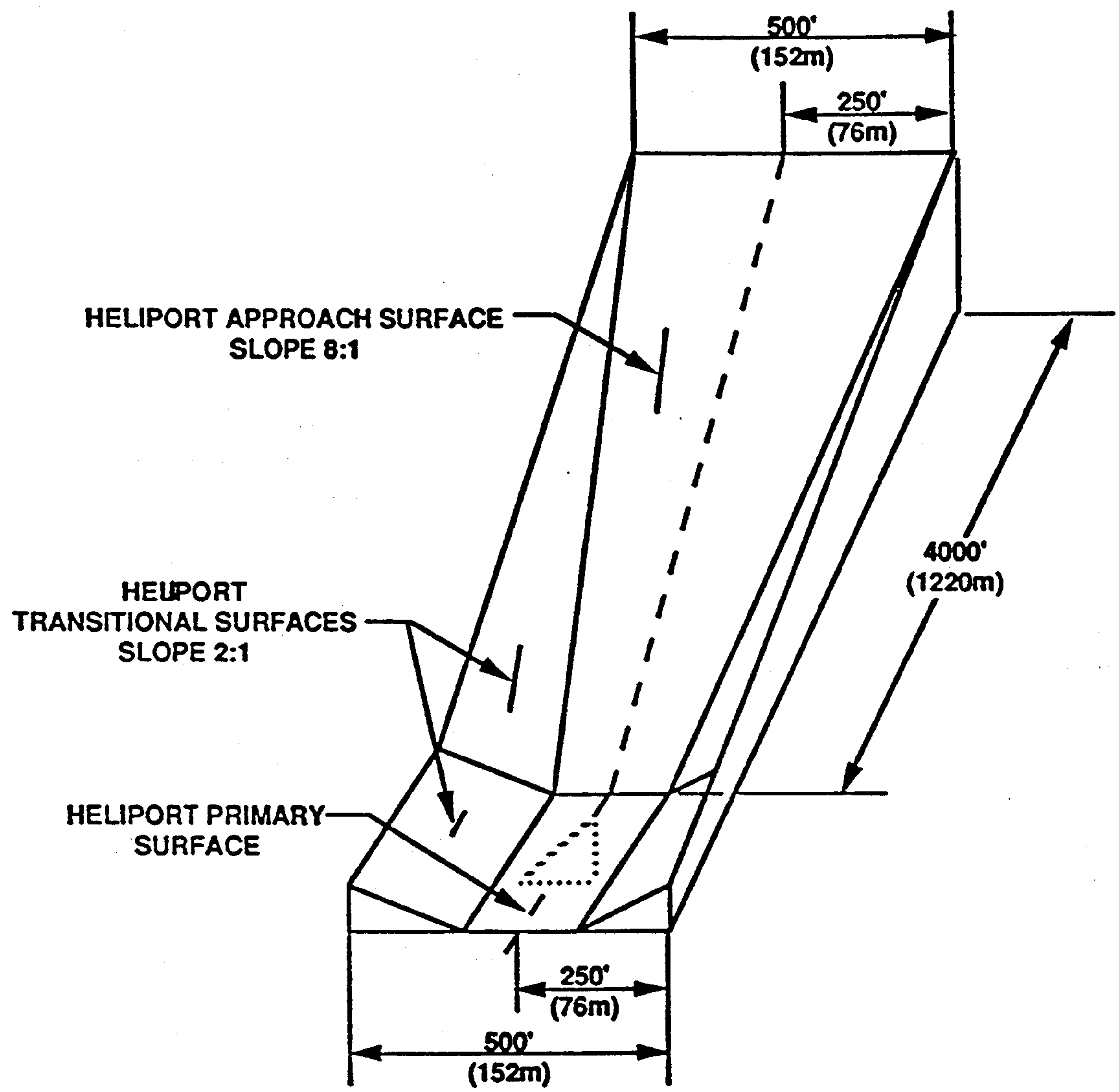


FIGURE 7-6. COMPARISON OF ALLOWABLE ELEVATION ANTENNA HEIGHTS

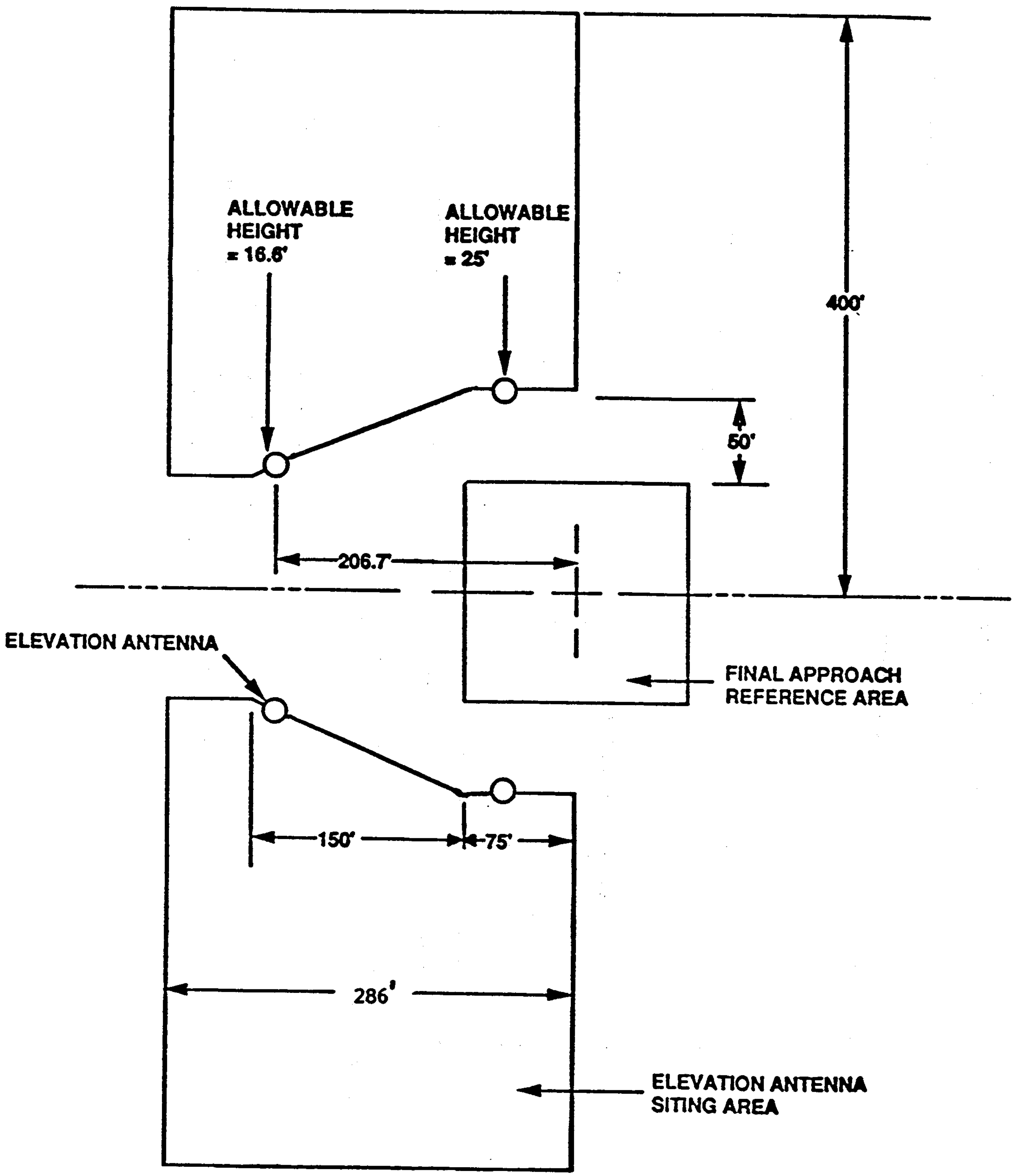
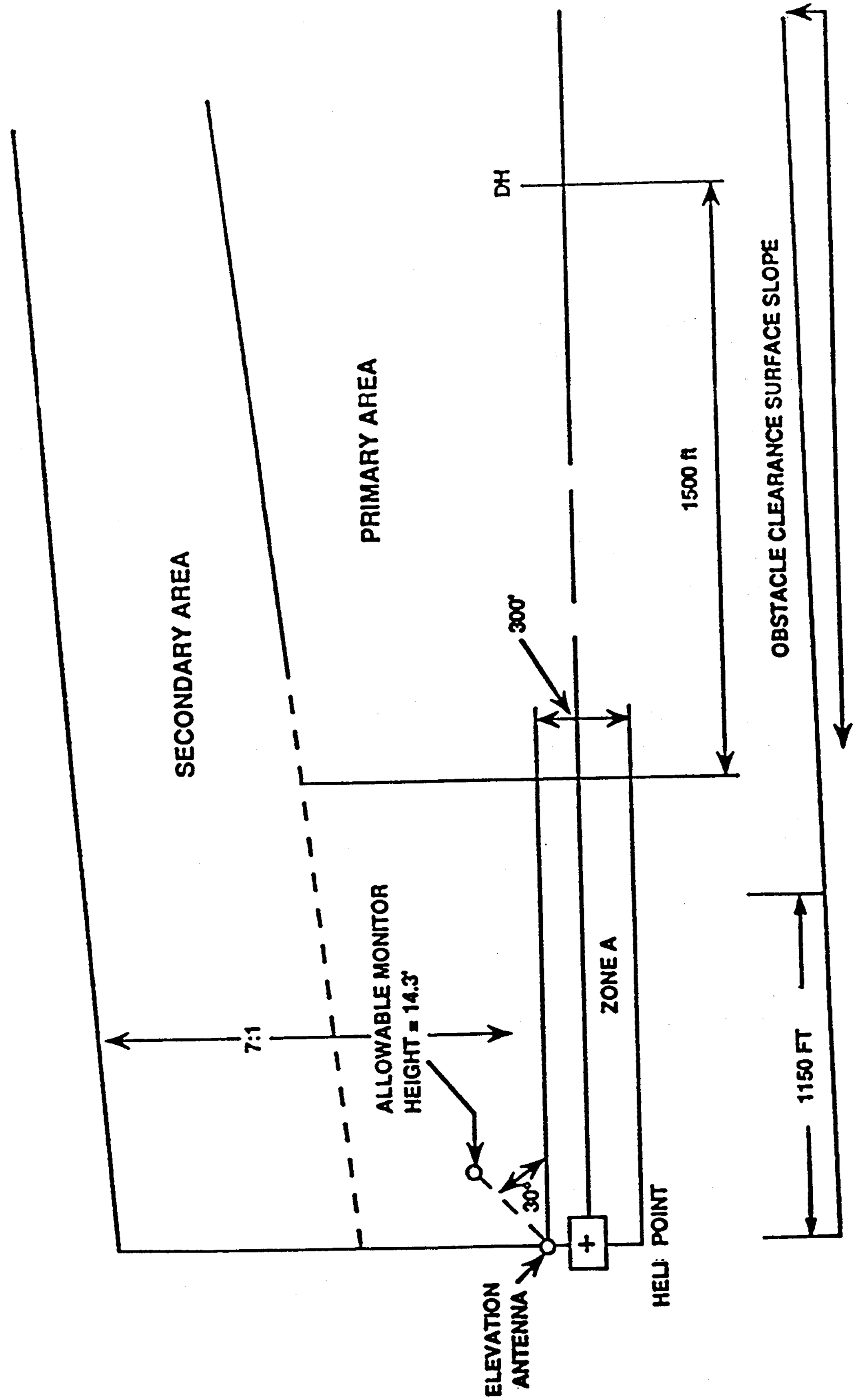


FIGURE 7-7. PRECISION APPROACH INSIDE SURFACE



712. DISTANCE REQUIREMENTS. Paragraphs 510 through 510c apply.

713.-799. RESERVED.

APPENDIX 1. GLOSSARY

Approach Azimuth: Equipment which provides lateral guidance to aircraft in the approach and runway regions. This equipment may radiate the approach azimuth function or the high rate approach azimuth function along with appropriate basic data.

Approach Elevation: The equipment which provides vertical guidance in the approach region. This equipment radiates the approach elevation function.

Auxiliary Data: Data, transmitted in addition to basic data, that provide ground equipment siting information for use in refining airborne position calculations and other supplementary information.

Back Azimuth: The equipment which provides lateral guidance in the back azimuth and runway regions. This equipment radiates the back azimuth function along with appropriate basic data.

Basic Data: Data transmitted by the ground equipment that are associated directly with the operation of the landing guidance system.

Beam Center: The midpoint between the -3 dB points on the leading and trailing edges of the scanning beam main lobe.

Beamwidth: The width of the scanning beam main lobe measured at the -3 dB points and defined in angular units on the antenna boresight, in the horizontal plane for the azimuth function and in the vertical plane for the Elevation function.

Clearance Guidance Sector: The volume of airspace, inside the coverage sector, within which the azimuth guidance information is not proportional to the angular displacement of the aircraft. Instead it is a constant fly-left or fly-right indication of the direction, relative to the approach course, that an inbound aircraft should fly in order to enter the proportional guidance sector. Also the corresponding volume of airspace in the Back Azimuth coverage sector for aircraft outbound.

Control Motion Noise (CMN): That portion of the guidance signal error which could affect aircraft attitude and cause control surface, wheel and column motions during coupled flight, but which does not cause aircraft displacement from the desired course or glidepath.

Coordinate System: Conical - A function is said to use conical coordinates when the decoded guidance angle varies as the minimum angle between the surface of a cone containing the receiver antenna, and a reference plane perpendicular to the axis of the cone and passing through its apex. The apex of the cone is at the antenna phase center and contains the zero-degree azimuth radial. For approach azimuth or back azimuth functions, the reference plane is vertical and contains the zero-degree azimuth radial. For elevation functions the reference plane is horizontal.

Coordinate System: Planar - a function is said to use planar coordinates when the decoded guidance angle varies as the angle between the plane containing the receiver antenna and a reference plane. For azimuth functions, the reference plane is the vertical plane containing the zero degree azimuth radial and the plane containing the receiver antenna is a vertical plane passing through the antenna phase center.

Coverage Sector: A volume of airspace within which service is provided by a particular function and in which the signal power density is equal to or greater than the specified minimum.

DME/P: The range function associated with the Microwave Landing Systems. It is a Distance Measuring Equipment (DME) that is compatible with standard navigation while providing improved accuracy and additional channel capabilities.

Effective Sidelobes: The level of antenna sidelobes which, when caused to interfere with the antenna main lobe under conditions of unity reflection and static worst-case phase, causes an error not exceeding a specified value.

Flare Coverage Zone: A zone that extends horizontally between the runway edges and longitudinally from 90 meters (300 feet) to 760 meters (2,500 feet) along the runway from threshold and vertically from near the runway surface to a height of 45 meters (150 feet).

Function: A particular service provided by the Microwave Landing Systems, e.g., approach azimuth guidance, back azimuth guidance or basic data.

Guidance Sector: The area on the ground, above which Microwave Landing Systems angle guidance is transmitted. The ground area frequently is a portion of a circle that is bounded by two radii and an intercepted arc.

Mean Course Error: The mean value of the azimuth error along a specified radial of an azimuth function.

Mean Glidepath Error: The mean value of the elevation error along the specified glidepath.

Minimum Glidepath: The lowest angle of descent along the zero-degree azimuth that is consistent with published approach procedures and obstacle clearance criteria.

MLS Approach Reference Datum: A point at a specified height located vertically above the intersection of the runway centerline and the threshold.

MLS Back Azimuth Reference Datum: A point at a specified height above runway centerline at the runway midpoint.

MLS Datum Point: The point on the runway centerline closest to the phase center of the approach elevation antenna.

Out-of-Coverage Indication (OCI) Signal: A signal radiated into areas outside the intended coverage sector where required, which causes an aircraft receiver warning indication in the presence of misleading guidance information.

Path Following Error (PFE): That portion of the guidance signal error which could cause aircraft displacement from the desired course or glidepath. These perturbations fall within the loop guidance bandwidth of an aircraft. The path following error is composed of the path following noise and the mean course error, in the case of azimuth functions, or the mean glidepath error, in the case of elevation functions.

Path Following Noise (PFN): That portion of the guidance signal error which could cause aircraft displacement from the mean course line or mean glidepath as appropriate.

Proportional Guidance Sector: The volume of airspace within which the angular guidance information provided by a function is directly proportional to the angular displacement of the airborne antenna with respect to the zero angle reference.

Runway Stop End: The location on the active runway which is the end of that runway. The aircraft approach is made to the end of the runway that is opposite to the runway stop end.

Time Division Multiplex (TDM): A method of sequentially transmitting a number of functions on a single frequency channel by means of time separation.

"TO" and "FRO" Scan: The first and second scans (respectively) of the scanning beam from one coverage limit to the other. The direction of the "FRO" scan is opposite to the direction of the "TO" scan.

APPENDIX 2. APPLICABLE DOCUMENTS

FAA Publications:

FAR, Part 77, Subpart C	Objects Affecting Navigable Airspace
FAR, Part 171, Subpart J	Microwave Landing Systems (MLS)
FAA-E-2721	Microwave Landing System (MLS)
FAA-C-2454	Facility Site Preparation
FAA-G-2100	Electronic Equipment, General Requirements
FAA-C-1217	Electrical Work, Interior
FAA-D-2494	Technical Instruction Book Manuscript; Electronic, Electrical, and Mechanical Equipment, Requirements for Preparation of Manuscript and Production of Books.
FAA-ER-530-81-04	Structural/Mechanical Design Requirements for Low Impact Resistance Microwave Landing System Structures (MLS/LIRS)
FAA-G-2300	Panel and Vertical Chassis, Rack
FAA-E-2734	Maintenance Management System - System Specification
FAA-E-2761	Cable, Fiber Optic, Multi-mode, Multifiber, Specification
Order 1050.1	Policies and Procedures for Considering Environmental Impacts

Order 2500.36	Application of Flight Hour Rates
Order 3900.19	Occupational Safety and Health
Order 6030.20	Electrical Power Policy
Order 6750.36	Site Survey, Selection, and Engineering Documentation for Instrument Landing Systems and Ancillary Aids
Order 6850.2	Visual Guidance Lighting Systems
Order 7110.65	Air Traffic Control
Order 7110.96	Air Traffic Control Facility Analysis Program for Microwave Landing System
Order 8240.50	Flight Inspection of Microwave Landing Systems (MLS)
Order 8260.3	United States Standard for Terminal Instrument Procedures (TERPS)
Order 8260.30	IFR Approval of Microwave Landing Systems (MLS)
Order 8260.34	Glide Slope Threshold Crossing Height Requirements
Order 8260.36	Civil Utilization of Microwave Landing System (MLS)
FAA-STD-002	Engineering Drawings
FAA-STD-016	Quality Control System Requirements
FAA-STD-019	Lightning Protection, Grounding, and Shielding Requirements for Facilities

FAA-STD-020	Transient Protection Grounding, Bonding, and Shielding Requirement for Equipment
FAA-STD-021	Configuration Management
FAA-STD-022	Microwave Landing System (MLS), Interoperability and Performance Requirements
FAA-STD-023	Microfilming of Engineering and Electrical Drawings
Advisory Circular 150/5300-13	Airport Design
Advisory Circular 150/5370-2	Operational Safety on Airports During Construction
Advisory Circular 150/5390-2	FAA Heliport Design Guide
Advisory Circular 120-28C	Criteria for Approval of Category III Landing Weather Minima
Advisory Circular 120/29	Criteria for Approving Category I and Category II Landing Minima for FAR 121 Operators
Advisory Circular 70/7460-1	Obstruction Marking and Lighting
Advisory Circular 150/5345-1	Approved Airport Lighting Equipment
NAS-MD-790	Interface Control Document (ICD) for the Remote Maintenance Monitoring System (RMMS)
NAS-MD-792	Management Document for Operation Requirements for the Remote Maintenance Monitoring System
NAS-MD-793	Remote Maintenance Monitoring System Functional Requirements for the Remote Monitoring Subsystem (RMS)

Information Documents:

[1] International Civil Aviation Organization,
International Standards and Recommended Practices,
Aeronautical Telecommunications, Annex 10.

[2] Radio Technical Commission for Aeronautics,
Minimum Operational Performance Standards for Microwave Landing System Airborne Receiver Equipment, Doc. No. DO-177

[3] Radio Technical Commission for Aeronautics,
Minimum Operational Performance Standards for Airborne Distance Measuring Equipment (DME) Operating Within the Frequency Range of 960-1215 MHz, Doc. No. DO-189.

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[1]Information on obtaining copies of ICAO documents may be obtained from the International Civil Aviation Organization , Suite 400. 1000 Sherbrook Street West, Montreal, Quebec, Canada H3A2R2.

[2]Information on obtaining copies of RTCA documents may be obtained from the Radio Technical Commission for Aeronautics, Suite 500, One McPherson Square, Washington, D.C. 20005.

[3]Ibid.

APPENDIX 3. LIST OF ACRONYMS

AAA	Airport Airspace Analysis
AC	Advisory Circular
ALS	Approach Lighting System
ARD	Approach Reference Datum
ATC	Air Traffic Control
BAZ	Back Azimuth
BDW	Basic Data Words
CMN	Control Motion Noise
DME	Distance Measuring Equipment
DPSK	Digital Phase Shift Keying
EA	Electronics Assembly
GPI	Ground Point of Intercept
HCH	Helipoint Crossing Height
HDIF	Height Difference
HMA	Helipoint Maneuver Area
HYBH	Hyperbolic Glidepath Height
ICAO	International Civil Aviation Organization
ICD	Interface Control Document
IFR	Instrument Flight Rules
ILS	Instrument Landing System
LIRS	Low Impact Resistance

MCE	Mean Course Path Error
MGE	Mean Glidepath Error
MGP	Minimum Glidepath Angle
MHz	Megahertz
MLS	Microwave Landing System
NAS	National Airspace System
nm	Nautical Miles
OCI	Out of Coverage
OCS	Obstruction Clearance Surface
OE	Observation Evaluation
OS	Offset
PFE	Path Following Error
PFN	Path Following Noise
RCSU	Remote Control Status Unit
RF	Radiofrequency
RMS	Remote Monitoring Subsystem
RMMS	Remote Maintenance Monitoring System
RSU	Remote Status Unit
SB	Antenna Setback Distance
TCH	Threshold Crossing Height
TDM	Time Division Multiplex
TERPS	Terminal Instrument Procedures

TRSB	Time Reference Scanning Beam
USGS	United States Geological Survey
VFR	Visual Flight Rules

*U.S. G.P.O.:1994-301-717:80510